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Work Plan for a Treatability Study in Support of the Intrinsic Remediation Option at PS-2

Fairchild Air Force Base
Spokane, Washington

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

and

92 CES/CEVR
Fairchild Air Force Base
Spokane, Washington

September 1995

PARSONS
ENGINEERING SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado 80290

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WORK PLAN FOR A TREATABILITY STUDY
IN SUPPORT OF THE INTRINSIC REMEDIATION OPTION AT PS-2

for

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

and

92 CES/CEVR
FAIRCHILD AIR FORCE BASE
SPOKANE, WASHINGTON

September 1995

by

Parsons Engineering Science, Inc.
1700 Broadway Suite 900
Denver, Colorado 80290

022/722450/FCWP/8.WW6

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SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering Science, Inc. (ES), presents the scope of work required for the collection of data necessary to conduct a treatability study (TS) for remediation of groundwater contaminated with petroleum hydrocarbons at the Flightline Operable Unit PS-2 (PS-2) located at Fairchild Air Force Base (AFB), 12 miles west of Spokane, Washington (the Base). Several groundwater remedial options will be evaluated as a part of the TS report, including: bioslurping; groundwater extraction, treatment, and disposal (i.e., pump and treat); biosparging; and natural contaminant attenuation (intrinsic remediation) with long-term monitoring. Hydrogeologic and groundwater chemical data necessary to evaluate the various remedial options will be collected under this program; however, this work plan is oriented toward the collection of hydrogeologic data to be used as input into groundwater flow and solute transport models in support of intrinsic remediation for restoration of groundwater contaminated with benzene, toluene, ethylbenzene, and xylene (BTEX).

As used in this report, the term “intrinsic remediation” refers to a management strategy that relies on natural attenuation mechanisms to remediate contaminants dissolved in groundwater and to control receptor exposure risks associated with contaminants in the subsurface. “Natural attenuation” refers to the actual physical, chemical, and biological processes that facilitate intrinsic remediation. Mechanisms for natural attenuation of BTEX include advection, dispersion, dilution from recharge, sorption, volatilization, and biodegradation. Of these processes, biodegradation is the only mechanism working to transform contaminants into innocuous byproducts. Intrinsic bioremediation occurs when indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without the addition of nutrients. Patterns and rates of intrinsic remediation can vary markedly from site to site depending on governing physical and chemical processes.

As part of the TS, the contaminant fate and transport modeling effort has three primary objectives: 1) predict the future extent and concentration of dissolved contaminant plumes by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) assess the possible exposure of potential downgradient receptors to contaminant concentrations that exceed levels intended to be protective of human health and the environment; and 3) to provide technical support for selection of the intrinsic remediation option as the best remedial alternative at regulatory negotiations, as appropriate. The modeling efforts for the PS-2 site at Fairchild AFB will involve completion of several tasks, which are described in the following sections.

This work plan was developed following discussions among representatives from the Air Force Center for Environmental Excellence (AFCEE), 92nd Civil Engineering Squadron--Environmental (92 CES/CEVR), and Parsons ES at a meeting held at the Base on July 11, 1995, to discuss the statement of work (SOW) for this project, and on a review of existing site characterization data. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993), and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and 92 CES/CEVR.

1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide a TS for remediation of groundwater contamination at PS-2. However, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with the US Environmental Protection Agency (USEPA) and Parsons ES to document the biodegradation and resulting attenuation of fuel hydrocarbons and solvents dissolved in groundwater, and to model this degradation using numerical and analytical groundwater model codes. For this reason, the work described in this work plan is directed toward the collection of data in support of this initiative. Data required to develop a 30-percent design of an alternate groundwater remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, also will be collected under this program. This work plan describes the site characterization activities to be performed by personnel from Parsons ES and the USEPA's Subsurface Protection and Remediation Division, formerly the USEPA's Robert S. Kerr Environmental Research Laboratory, in support of the TS and the groundwater modeling effort. Field activities will be performed to determine the extent of mobile and residual light nonaqueous-phase liquid (LNAPL) and dissolved contamination at PS-2. The data collected during the TS will be used along with data from previous investigations to complete the characterization of contamination at the site, and for use in the groundwater flow and solute transport models to make predictions of the future concentrations and extent of contamination.

Site characterization activities in support of the TS will include: 1) determination of preferential contaminant migration and potential receptor exposure pathways; 2) soil sampling using the Geoprobe® direct- push technology; 3) groundwater monitoring point placement; 4) groundwater sampling; and 5) aquifer testing. The materials and methodologies to accomplish these activities are described herein. Previously reported site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the groundwater flow and solute transport models. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site will be obtained from widely accepted published literature and used for model input. Sensitivity analyses will be conducted for the parameters that are known to have the greatest influence on the model results, and where possible, the model will be calibrated using historical site data. Upon completion of the modeling, Parsons ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not the most appropriate remedial option, Parsons ES will recommend the most appropriate groundwater remedial technology on the basis of available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of available previously reported, site-specific data and conceptual models for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and TS report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. There are two appendices to this work plan. Appendix A contains a listing of containers, preservatives, packaging, and shipping requirements for soil and groundwater samples. Appendix B contains summary site data, including available well logs, and summaries of historical soil and groundwater analytical data from previous field investigation work.

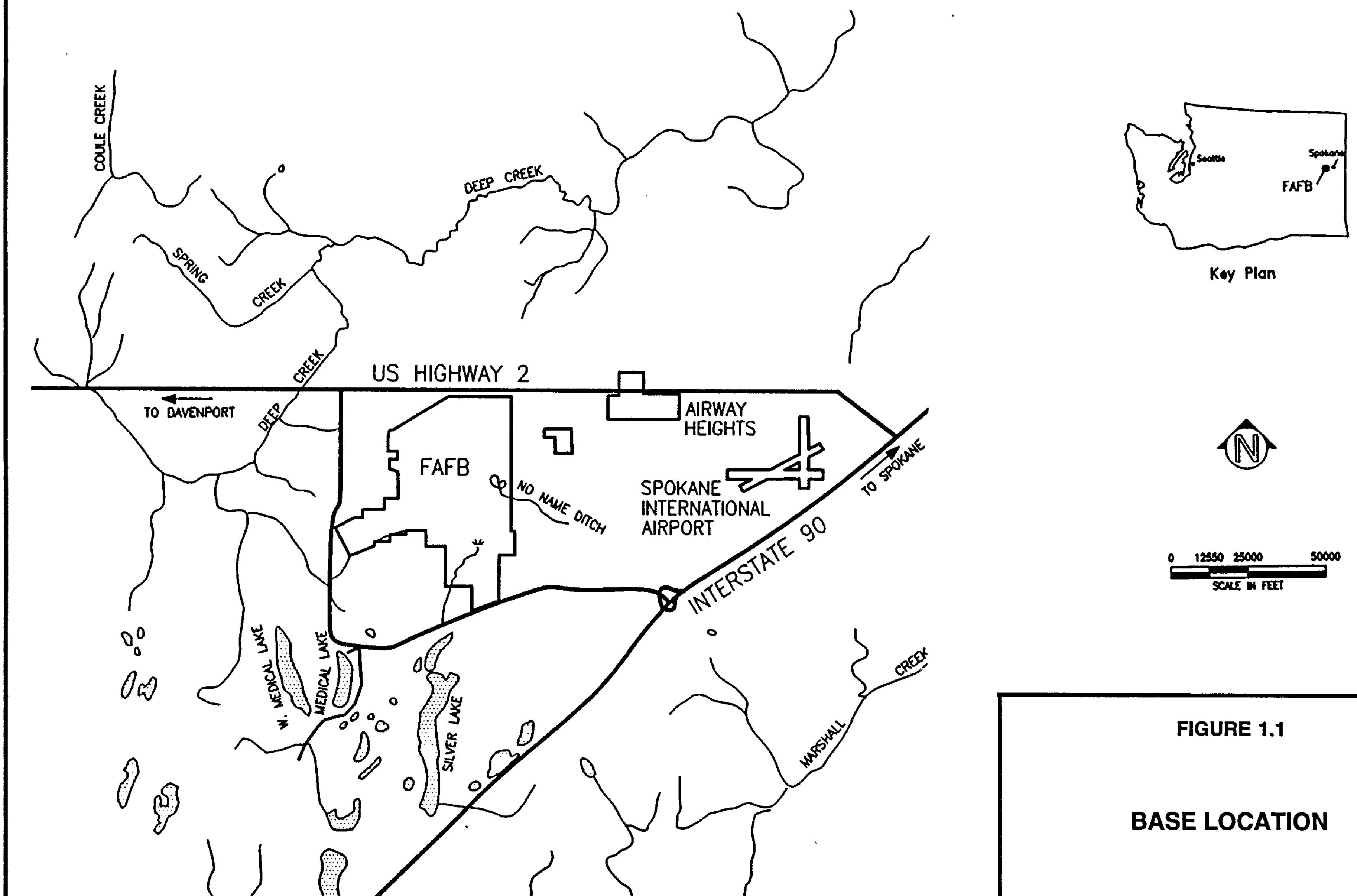
1.2 BACKGROUND

Fairchild AFB occupies an area of approximately 4,300 acres 12 miles west of Spokane, Washington (Figure 1.1). The Base is divided roughly in half by the main northeast/southwest runway (Figure 1.2). Aircraft operational facilities, approximately 1,600 Base housing units, an elementary school, a hospital, and support facilities for the tenants housed on-Base lie north of the runway. The air traffic control tower, weapons storage area, and survival training school lie to the south of the runway [Halliburton NUS (HNUS), 1993].

The Base was established in 1942 as an Army repair depot and transferred to the Strategic Air Command (SAC) in 1947. In 1992, Base control was transferred to the Air Combat Command (ACC). Currently, the Base is operated by the Air Mobility Command (AMC) and serves as host to the 92nd Air Refueling Wing. The Base is also the current home of the 141st Air Refueling Wing of the Washington Air National Guard (WANG), aircraft operational facilities, a weapons storage area, and a survival training school. Base operations employ approximately 5,000 civilian and military personnel (ES, 1994).

PS-2 is an active aircraft fueling/defueling station located on the flightline in the western portion of the Base and is a part of the flightline operational unit (OU-1). More specifically, PS-2 is located along Taxiway 1, in front of Buildings 1029, 1033, and 1037 in the WANG portion of Fairchild AFB (Figure 1.3). The site is covered by a broad expanse of asphalt and concrete with five refueling/defueling pits (Pits 17 through 21) located within the site boundaries (ES, 1994).

Two fuel spills have been documented at PS-2. In 1984, the fuel tank at defueling/refueling Pit 18 is known to have leaked up to 120 gallons of JP-4 jet fuel (HNUS, 1993). In 1985, an estimated 5,000 gallons of JP-4 was spilled when a fuel line flange cracked at Pit 21, located south of Building 1037. Reportedly, 4,000 gallons of fuel were recovered during the following 4 days. The spill overflowed the storm sewer system at the manhole in front of Building 1033, 400 feet downgradient. Fuel was also detected in a sewer junction box an additional 600 feet further downgradient from the release point. Approximately 100 gallons of fuel was pumped from this sewer junction box onto a grassy area east of Building 1029. Areas reportedly affected by the spills are indicated on Figure 1.3.



Source: ICF Technology Inc., 1995.

FIGURE 1.1

BASE LOCATION

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

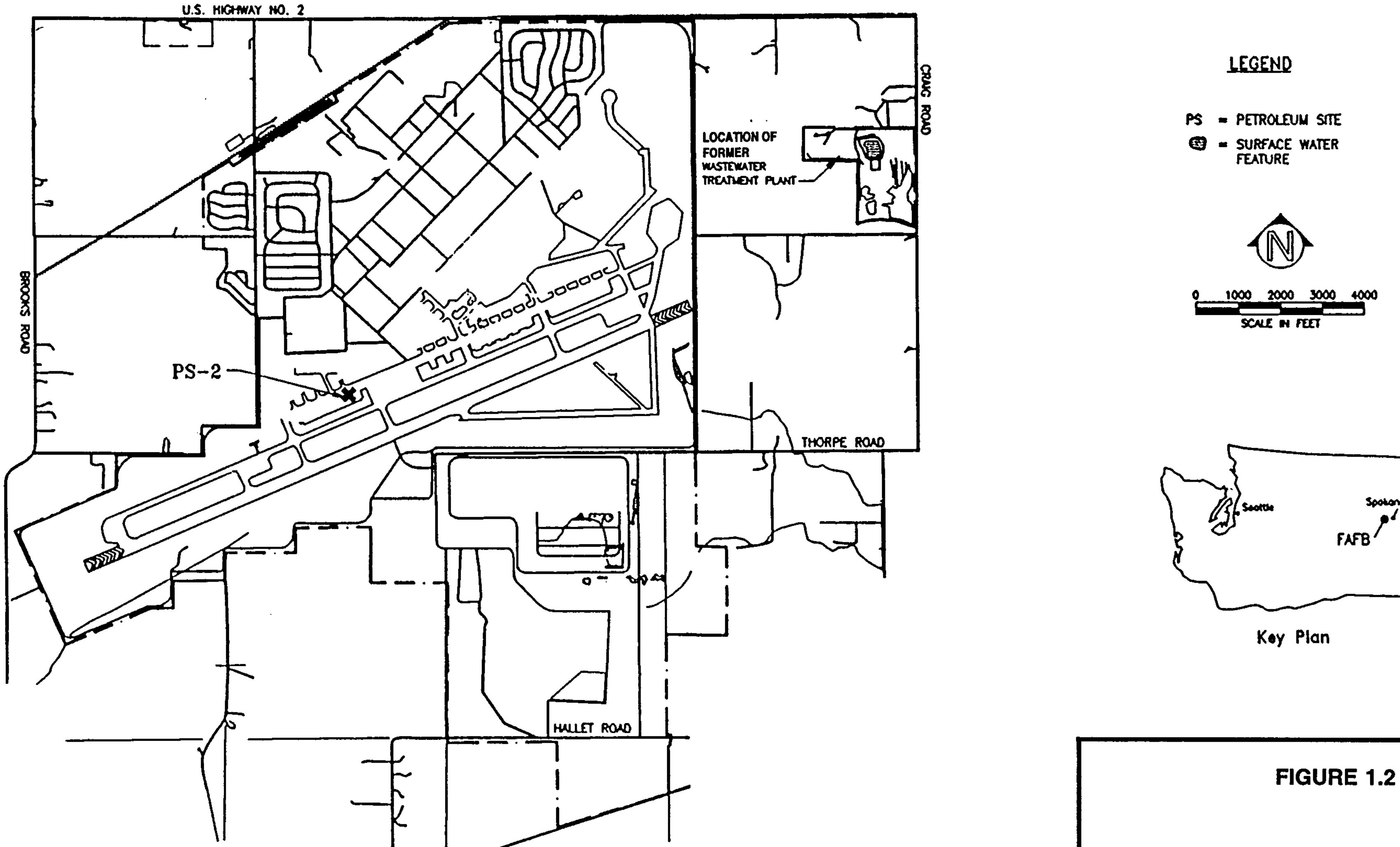


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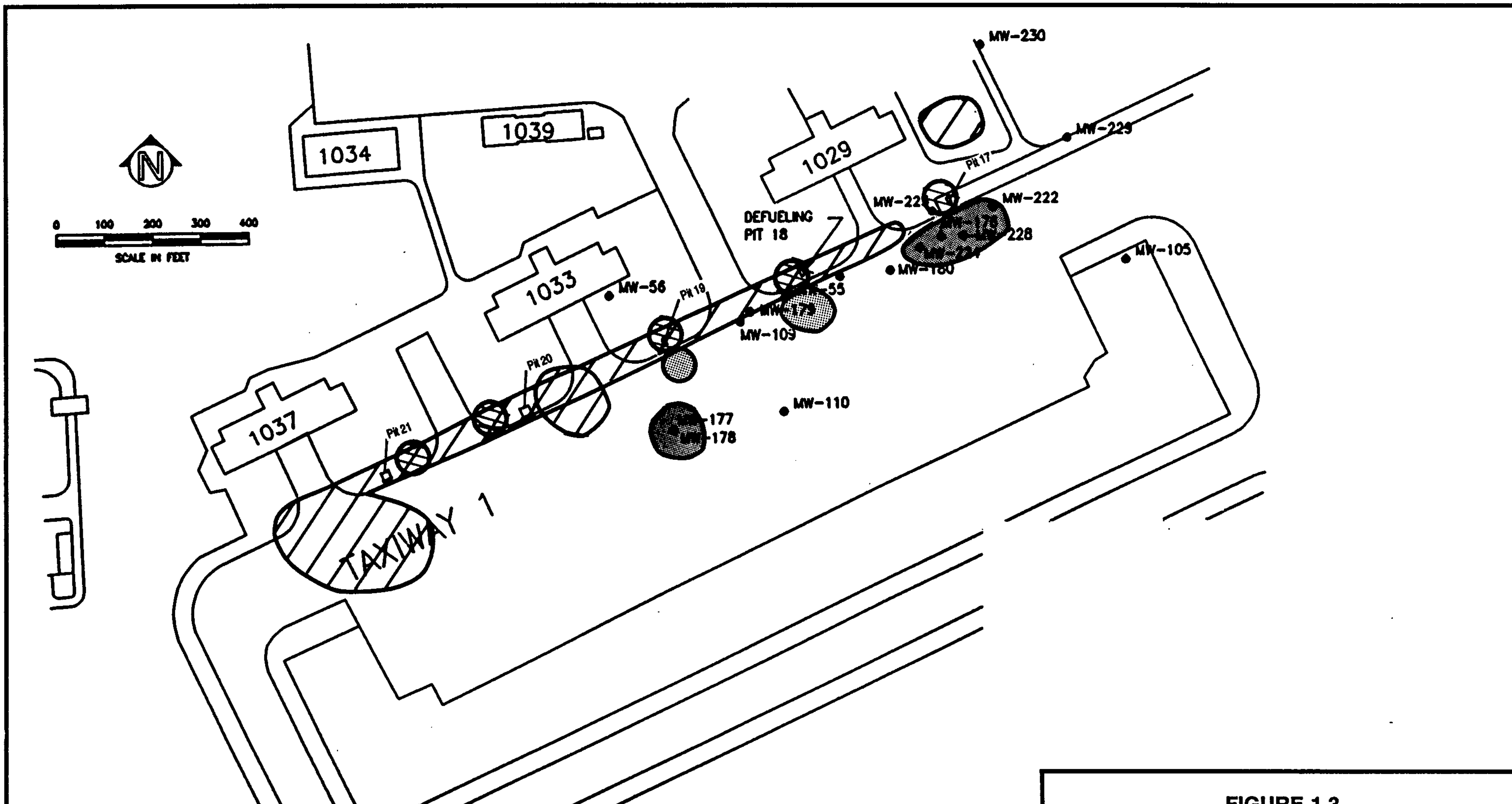
FIGURE 1.2

SITE LOCATION

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



LEGEND

AREAS DOCUMENTED TO HAVE BEEN INPACTED DURING 1985 AND 1984 FUEL SPILLS.

LOCATIONS KNOWN TO CONTAIN FUEL TRANSFER EQUIPMENT.

REGIONS OF UNSATURATED SOIL CONTAMINATION.

REGIONS OF MOBILE LNAPL.

MW-112 MONITORING WELL

Sources: ICF Technology Inc., 1995.

FIGURE 1.3

SITE PS-2 LAYOUT

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS
ENGINEERING SCIENCE, INC.
Denver, Colorado

Investigations were initiated at PS-2 as a result of the reported spills and the identification of petroleum product in the groundwater during flightline foundation drilling. The groundwater contamination later was confirmed in the Installation Restoration Program (IRP) Phase II study by Battelle Laboratories (1989). Since that time, a remedial investigation (RI) has been completed by HNUS (1993), a long-term monitoring report has been completed by ICF Technology (ICF, 1995), a source removal TS has been completed by HNUS (1994 , 1995a and 1995b), an interim bioventing report has been completed by ES (1994), and an analytical informal technical information report (ITIR) for long-term groundwater monitoring has been submitted by EA Engineering, Science, and Technology and Montgomery Watson Americas, Inc. (ES&T and MWA), (1995).

To date, mobile LNAPL has been identified in the vicinity of monitoring wells MW-177 and MW-176 (HNUS, 1993). LNAPL also was found in a vapor monitoring point during the installation of a bioventing pilot test system in the vicinity of defueling/refueling Pit 19. The soils near defueling/refueling Pit 19 were heavily contaminated with fuel hydrocarbons and residual LNAPL and are a probable continuing source of groundwater contamination (ES, 1994). The relationship between these three source areas and the former spills is unclear. The three source areas are identified on Figure 1.3. It is suspected that other unidentified sources also may be present at the site; all previously documented fuel distribution facilities are identified on Figure 1.3.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Previously reported site-specific data were reviewed and used to develop a conceptual site model (CSM) for the groundwater flow and contaminant transport conditions at PS-2. The CSM guides the development of sampling locations and analytical data requirements needed to support the modeling efforts and to evaluate potential remediation technologies, including intrinsic remediation. Section 2.1 presents a synopsis of available site characterization data. Section 2.2 presents the preliminary conceptual groundwater flow and contaminant transport model that was developed based on these data.

2.1 DATA REVIEW

The following sections are based upon review of data from the following sources:

- Remedial Investigation/Feasibility Study (RI/FS) Site Characterization Summary Report Priority 1 Sites Fairchild AFB [Science Applications International Corporation (SAIC), 1990];
- IRP Remedial Investigation Report (HNUS, 1993);
- Bioventing Pilot Test Results Report for PS-2, PS-1A, PS-1B, Building 2034, and Building 2035 (ES, 1994);
- Work Plan for Floating Free Product Passive Recovery TS (HNUS, 1994a);
- Floating Free Product Passive Recovery TS Letter Reports 07, 08, and 09 (HNUS, 1994b, 1995a, and 1995b);
- Long Term Monitoring Report For Priority 1 Sites SW-1 (LF-01), PS-2 (SS-18), and PS-8 (SS-26) at Fairchild AFB, Washington (ICF, 1995); and
- Analytical ITIR: Long-Term Monitoring, April Sampling Craig Road Landfill and Priority Sites SQ-1 PS-2, PS-8, and FT-01 (ES&T and MWA, 1995).

Several other reports contain site information that may be useful during the development of fate and transport models. These documents, which were unavailable during the development of this work plan, include:

- IRP Phase II, Stage 1 Confirmation/Qualification, Stage 1 Fairchild AFB (Battelle Laboratories, 1989); and

- IRP Phase I Records Search, 92nd Bombardment Wing, Fairchild AFB (JRB Associates, 1985).

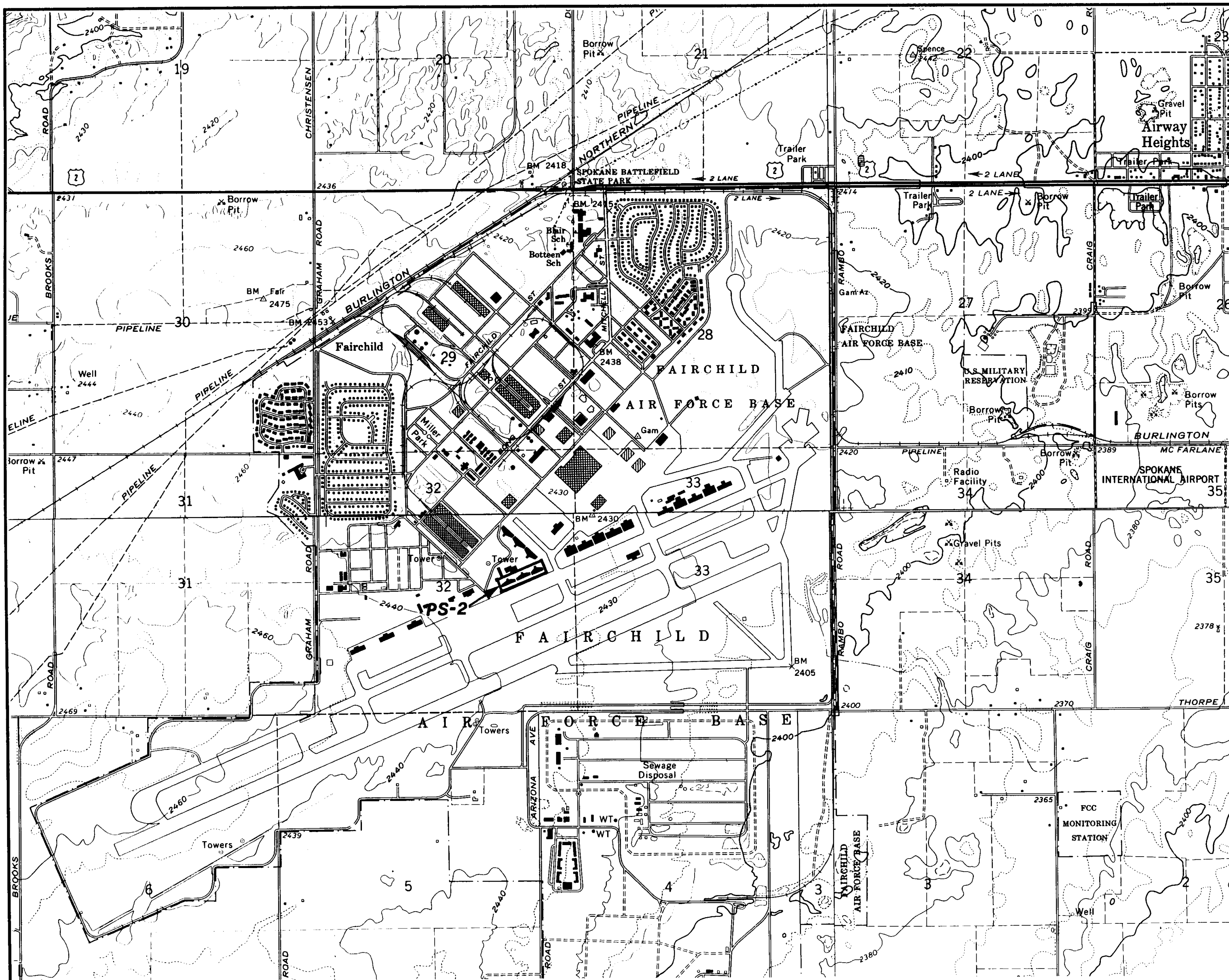
2.1.1 Topography, Surface Hydrology, and Climate

Fairchild AFB is located within the Columbia Basin in the northeastern corner of the 55,000-square-mile Columbia Plateau Physiographic Province (ICF, 1995). The Columbia Plateau is bordered by mountains and highlands on all side. The northern edge of the Plateau gives way to the Okanogan Highlands roughly 75 miles north of Fairchild AFB, while the eastern end of the Plateau is bordered by the Rocky Mountains, approximately 75 miles east of Fairchild AFB. The Plateau extends approximately 250 miles to the south and west of the Base; the Blue Mountains border the Plateau on the south, and the Cascade Mountains border the Plateau on the west. There is a watershed divide in the center of the Plateau that causes streams north of this divide to flow in a northerly direction, and streams south of the divide to flow in a southerly direction. The topography of the region was shaped by glacial flood waters which deeply that eroded the surface of the Columbia Plateau during the Pleistocene Epoch (approximately 22,000 years ago) (HNUS, 1993). The surface topography of the Base and surrounding region is generally flat to gently rolling grasslands sloping slightly to the east-northeast. Ground surface elevations on the Base range from 2,400 to 2,460 feet above mean sea level (ft msl) (Figure 2.1).

Fairchild AFB is locate in the northern half of the Columbia Plateau, north of the of the watershed divide. All surface water drainage in this region of the Columbia Plateau generally flows to the north or northwest (Flint, 1936). The Base is approximately 7 miles west-southwest of the Spokane River, which flows through the city of Spokane (USGS, 1973a, 1973b, 1986a, and 1986b). Two other drainages in the vicinity of the Base are Deep Creek and Marshall Creek, located approximately 2 miles northwest and 8 miles southeast of the Base, respectively. These creeks flow northwest and join the Spokane River, which drains this region of the Plateau. Surface water on the Base is generally limited to precipitation runoff. Surface water drainage is controlled within a series of manmade ditches. Reportedly, water collected in the ditch system does not leave Base property and surface water either infiltrates the subsurface or evaporates (HNUS, 1993).

Surface runoff at PS-2 is controlled through storm sewers that run parallel to Ladder Taxiway No. 1 (Figure 1.3). Three storm sewer lines drain the tarmac to the northeast where one main line collects all three storm sewer lines and eventually flows southeast into the wastewater lagoons (WW-1) located in the southern corner of the base. A map of these sewer lines is included in Appendix B. Buildings 1027, 1033, and 1029 have floor drains which pass through oil/water separators. The effluent from the separators flows into the storm sewer network (HNUS, 1993).

Fairchild AFB is surrounded by semi-arid grasslands common to this area of the Columbia Basin. The Base receives approximately 16 inches of rainfall during the warm dry summers, and 40 inches of snowfall during the cool, damp winter months. The prevailing wind direction in the region is to the northeast at an average speed of 8 miles per hour (ICF, 1995). The average evapotranspiration rate for the region is reported at 12.8 inches per year (JRB Associates, 1985). Maximum infiltration rates usually occur during the early spring when snow melt runoff combines with



Sources: USGS, 1973A, 1973B, 1973C, and 1986.

FIGURE 2.1

REGIONAL TOPOGRAPHIC BASE MAP

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.

precipitation while temperatures are still cool and evapotranspiration is low (SAIC, 1990).

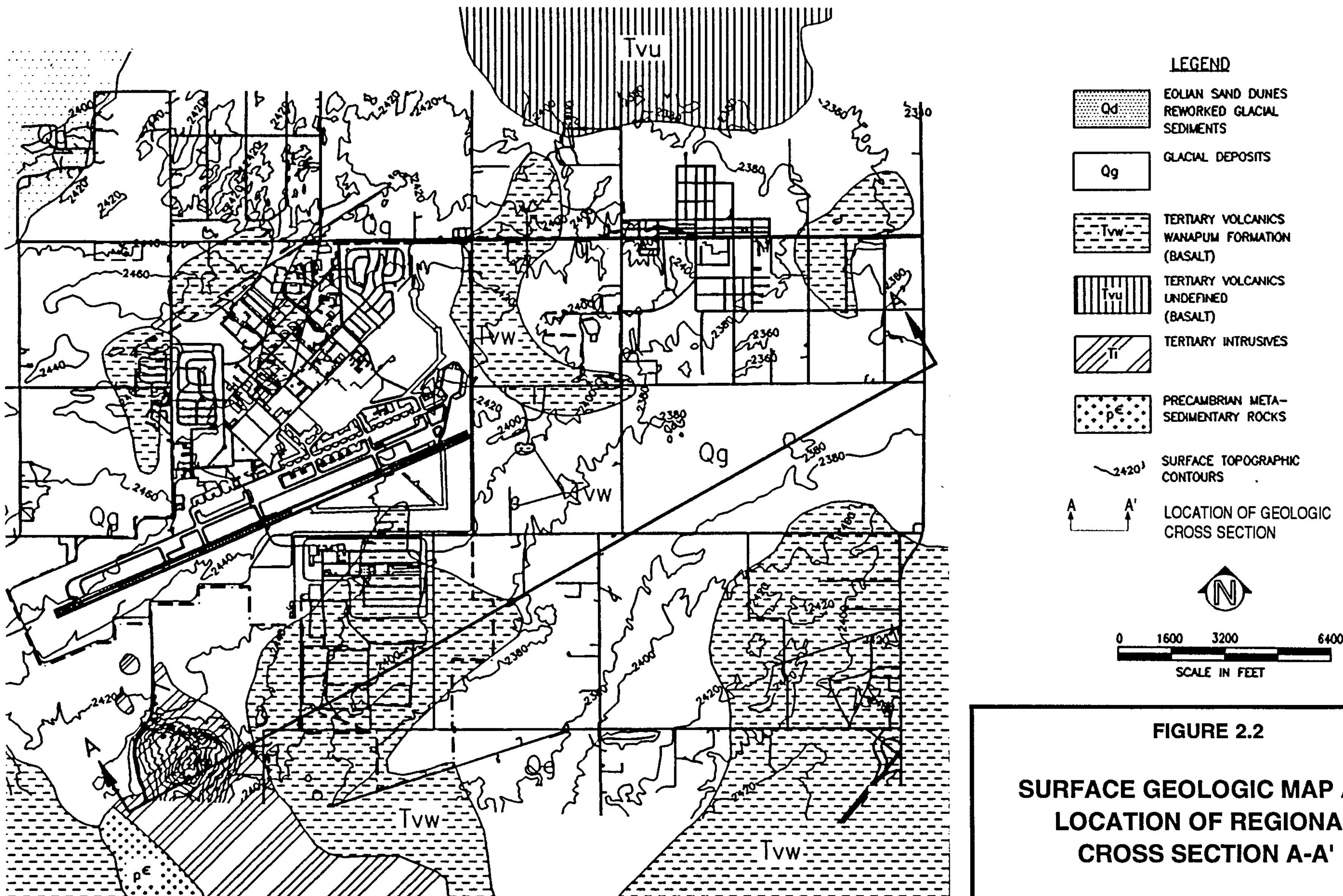
2.1.2 Overview of Geology and Hydrogeology

2.1.2.1 Regional Geology and Hydrogeology

The shallow subsurface geology at Fairchild AFB is a mixture of Quaternary sediments consisting of eolion, glacial, fluvial, lacustrine, and catastrophic flood deposits (Figure 2.2). Flood waters from the glacial-era Missoula Lake scoured the basalt bedrock of this region of the Columbia Plateau. Coarse sediments were deposited during the early recession of flood waters, followed by finer sediments during the later stages of floodwater recession. The alluvium in the vicinity of the Base generally consists of fine-grained sediments deposited by receding glacial flood waters. Clays and silts are intermixed with sandy silts, clays, and gravels (SAIC, 1990). Additionally, loess (windblown silt) deposits are interbedded in portions of the alluvium. Alluvial deposits are generally follow the slope of the underlying basalt bedrock (ICF, 1995).

Bedrock in the vicinity of the Base is mostly Tertiary Basalts of the Columbia River Group. Basalts below Fairchild AFB are of the Wanampum Formation (HNUS, 1993). The basalt flows in the region are interbedded with sedimentary clay and silt units of the of the Latah Formation. These layers were deposited when stream beds were isolated by the volcanic basalt flows (Cline, 1969). The Wanampum Basalt flow below the Base appears to be divided into an upper and lower flow sequence by an interbed of the Latah Formation (Figure 2.3). The upper basalt flow is 166 feet to 193 feet thick across the Base. The surface of the upper basalt flow is vesiculated, deeply fractured, and highly weathered in places. Just east of the Base the upper basalt layer was completely eroded away by the Missoula Lake flood waters. The middle of this flow contains few vesicles and fractures; the formation becomes more massive and competent with depth. The underlying Latah Formation deposits consist of an extensive silty claystone that ranges in thickness from 8.5 to 10 feet (SAIC, 1990). Information on the geologic characteristics of the lower basalt flow was not available in the previous reports reviewed as part of this work plan; however, information on the lower basalt flow is not considered to be vital to the formation of the CSM for data collection in support intrinsic remediation at PS-2.

Groundwater in the vicinity of the Base is encountered between 8 to 12 feet below ground surface (bgs) and is found in both the alluvial overburden material and the underlying basalt bedrock. Groundwater flow in the alluvium is through intergranular pore space, while flow in the basalt is through interconnecting fractures (HNUS, 1993). Flow across the Base is generally to the east and east-northeast, but local variations may result from local changes in bedrock topography (Figure 2.4). Groundwater in the overburden and shallow bedrock is generally unconfined, with some local semiconfined areas. The overburden and the shallow basalt are hydraulically connected by fractures, vesicles, and weathered zones. The middle region of the shallow basalt flow is more competent with less fracturing, and acts as an aquitard. The interbedded claystone between the basalt flows also acts as a confining layer (HNUS, 1993).



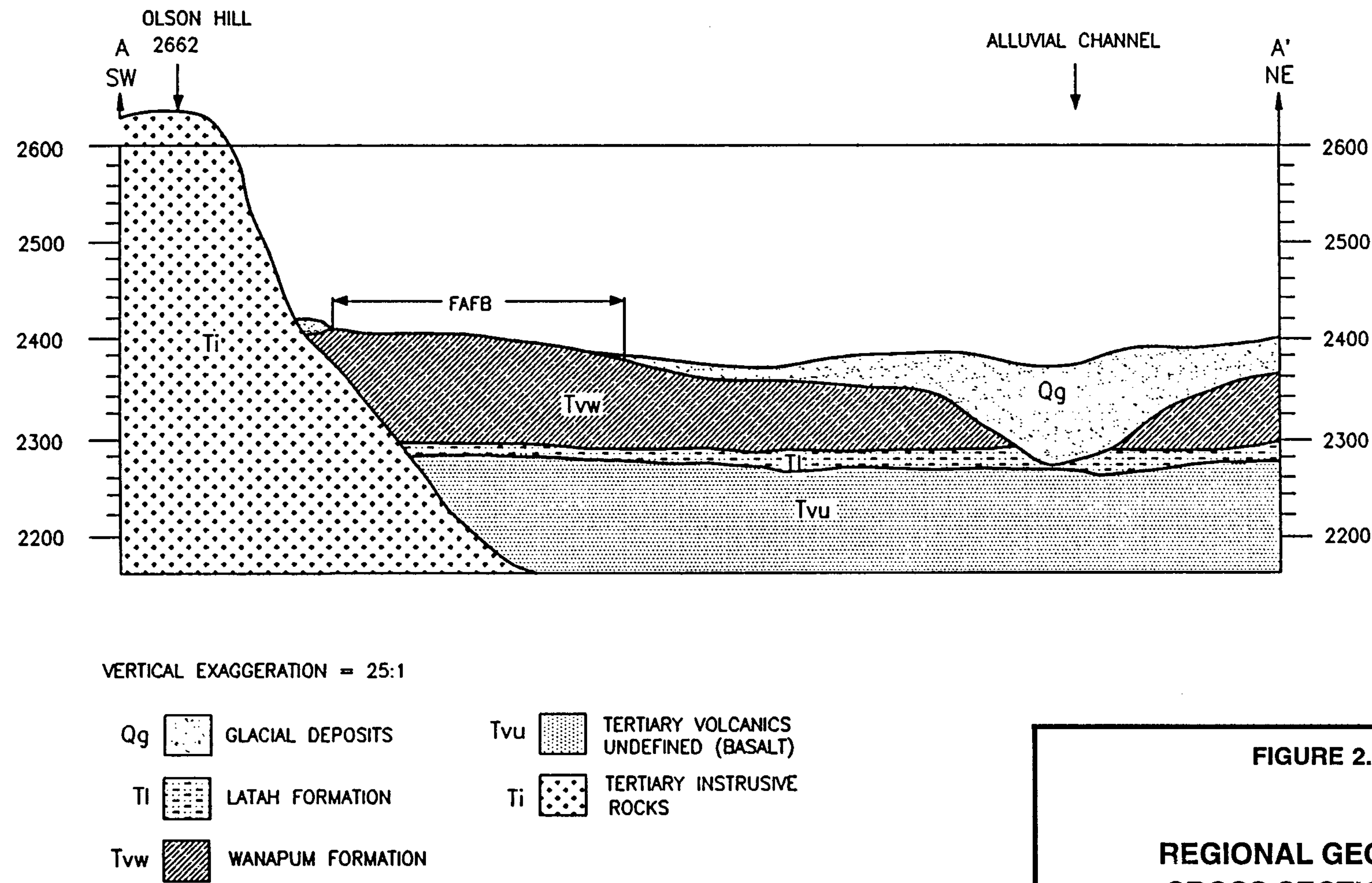
Source: ICF Technology Inc., 1995.

FIGURE 2.2

SURFACE GEOLOGIC MAP AND LOCATION OF REGIONAL CROSS SECTION A-A'

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



Source: ICF Technology Inc., 1995.

FIGURE 2.3

REGIONAL GEOLOGIC CROSS SECTION A-A'

Intrinsic Remediation TS
Fairchild AFB, Washington

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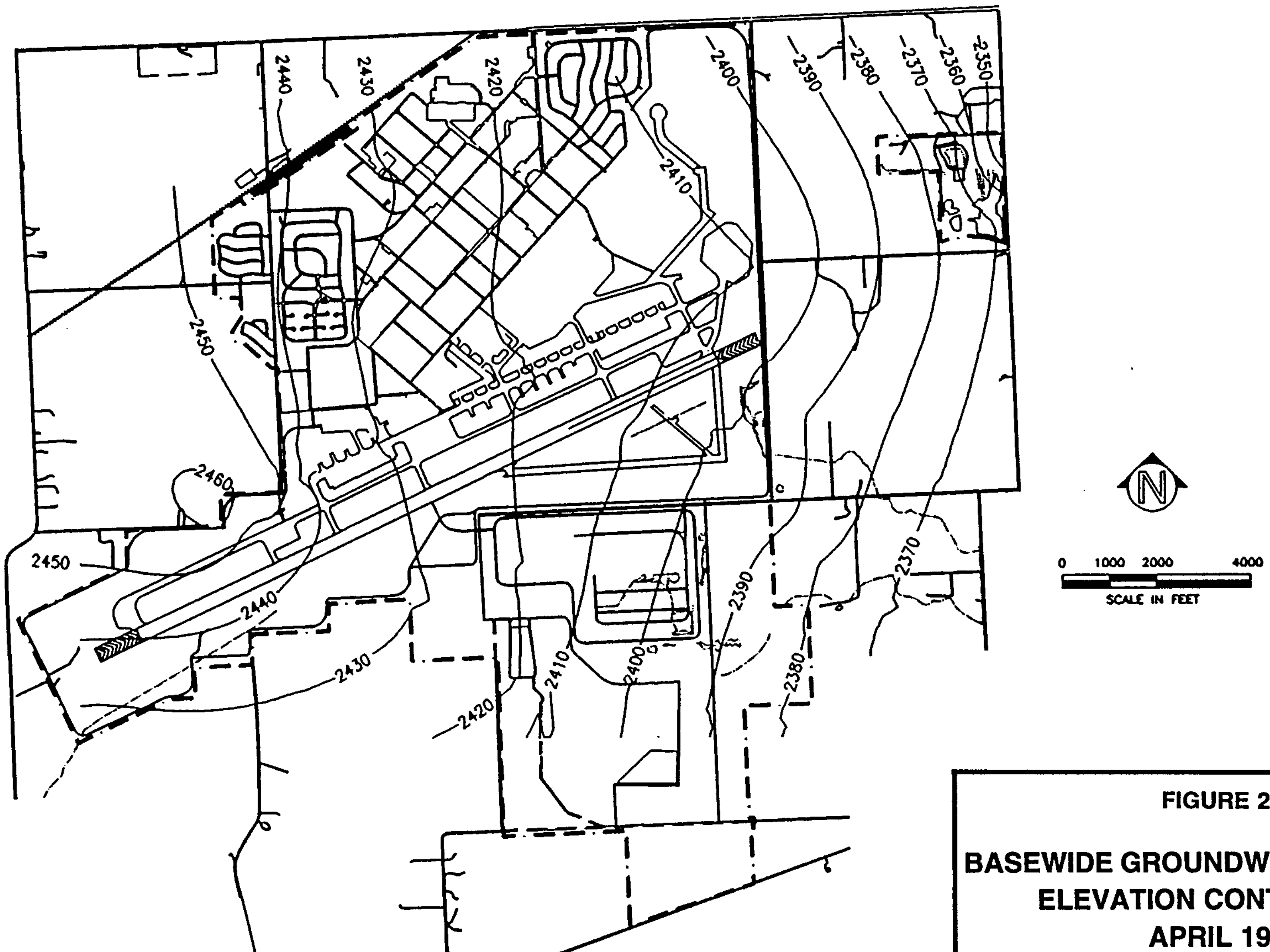


Source: ICF Technology Inc., 1995.

FIGURE 2.4

BASEWIDE GROUNDWATER SURFACE ELEVATION CONTOUR MAP APRIL 1993

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

Recharge of the aquifer under the Base is expected to come from upgradient flow and surface runoff infiltration. Shallow groundwater in the vicinity of the Base is not known to be used as a drinking water supply. Neighborhoods to the east and northeast of the Base obtain domestic and agricultural water primarily from private wells which tap aquifers in the deeper basalt flows. The closest residential neighborhoods are roughly 1.5 miles downgradient from the site, near the eastern boundary of the Base. Base drinking water is primarily supplied from a Base-owned well field 10 miles northwest of the Base. Additionally, there is a water supply well located in the southern area of the Base. This well also produces water from the basalt aquifer and supplies roughly 10 percent of the Base's needs (HNUS, 1993).

2.1.2.2 PS-2 Geology and Hydrology

Most of the ground surface at PS-2 is covered by concrete and asphalt pavement for parking, maintenance, and fueling of aircraft. The thicknesses of the concrete and asphalt are not available at this time; however, the concrete pavement is expected to be at least 8 inches thick. On the basis of information collected during the RI and other previous investigations, the overburden at PS-2 is from 15 to 24 feet thick. Sediments at PS-2 consist primarily of poorly sorted silty and gravelly sands and sandy gravels. A clay and sandy clay layer was encountered just above the overburden basalt interface in several wells installed as part of the RI. The upper flow zone basalt layer below the alluvial deposits is massive, moderately fractured, and shows traces of weathering near the overburden basalt interface (HNUS, 1993).Figure 2.5 shows the location of stratigraphic cross sections A-A' and B-B'. Figure 2.6 presents cross section A-A' which is oriented in a northeast-southwest direction along the axis of groundwater flow. Figure 2.7 presents cross section B-B', oriented perpendicular to the direction of groundwater flow in a northwest-southeast direction.

Borehole logs from the vent well (VW-1) and vapor monitoring points (VMPs) installed during the bioventing pilot test near defueling pit 19 showed that soils from the surface to 2 feet bgs were a gray to grayish-green gravelly sand. Below 2 feet soils were mostly a brown to greenish-gray silty sand with minor gravel. Soils from both intervals exhibited a noticeable fuel odor. A clean sand lens was encountered roughly 5 feet bgs, and a dark-brown clay lens was encountered at a depth of 9 feet bgs in the borehole associated with VW-1. The clay lens also exhibited a noticeable fuel odor (ES, 1994).

There are currently twenty-two groundwater monitoring wells at PS-2 including 3 wells with screening in the shallow basalt bedrock, and 17 wells with screening in the unconsolidated deposits. These wells were installed as part of the RI/FS site characterization investigation, the RI, the long-term monitoring program, and the mobile LNAPL recovery TS. Groundwater at the site resides in the Quaternary alluvium and in the underlying basalt bedrock. Available monitoring well construction details and recent well level data are presented in Table 2.1. Figure 2.8 shows the groundwater surface for PS-2 in October 1993. The groundwater surface shown on Figure 2.8 is very similar to those reported in previous site investigations reports, implying that groundwater flow patterns remained consistent.

In the immediate vicinity of the site, groundwater flows to the east-northeast, which is consistent with the regional flow direction. Groundwater elevations typically are

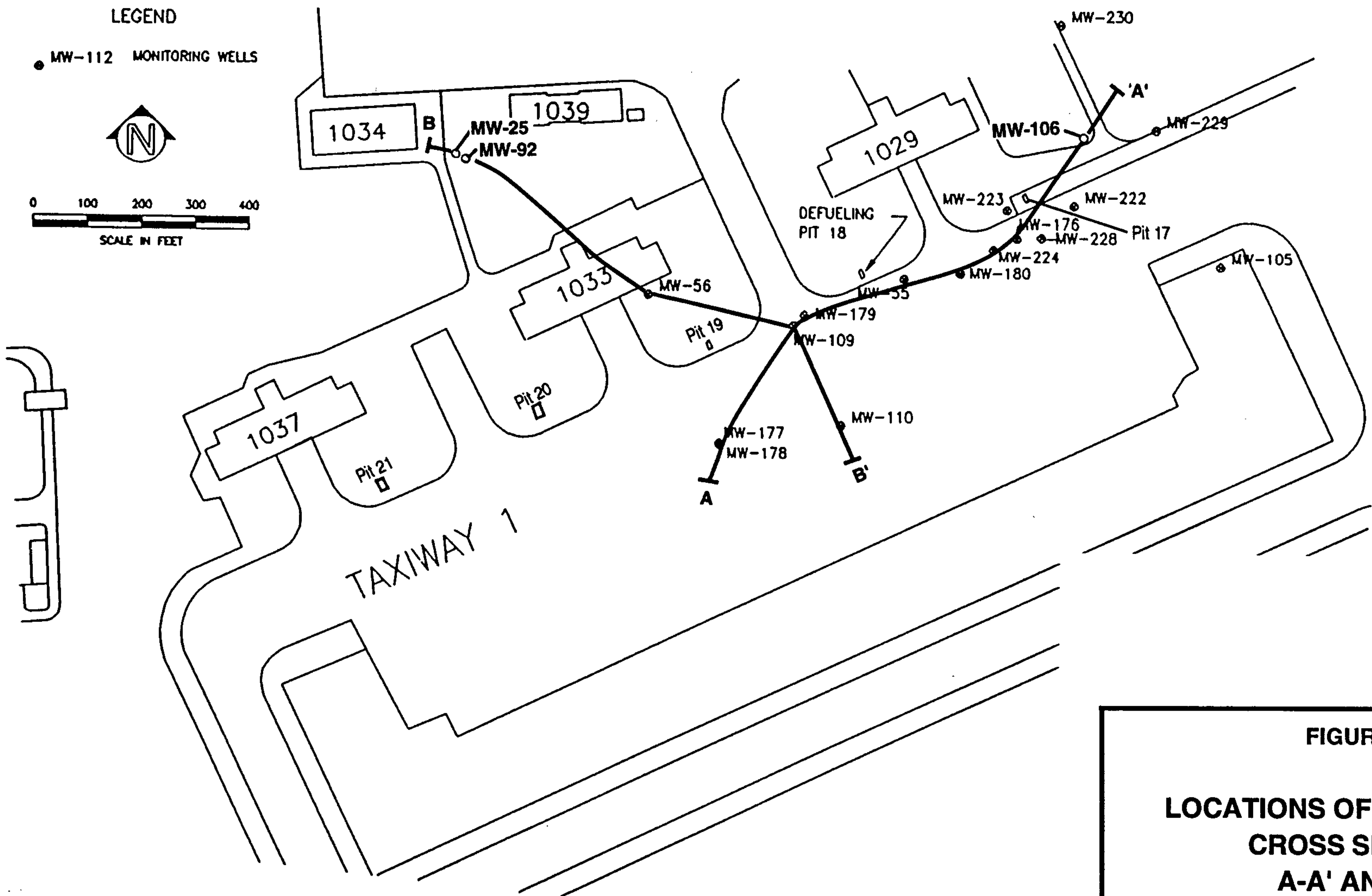


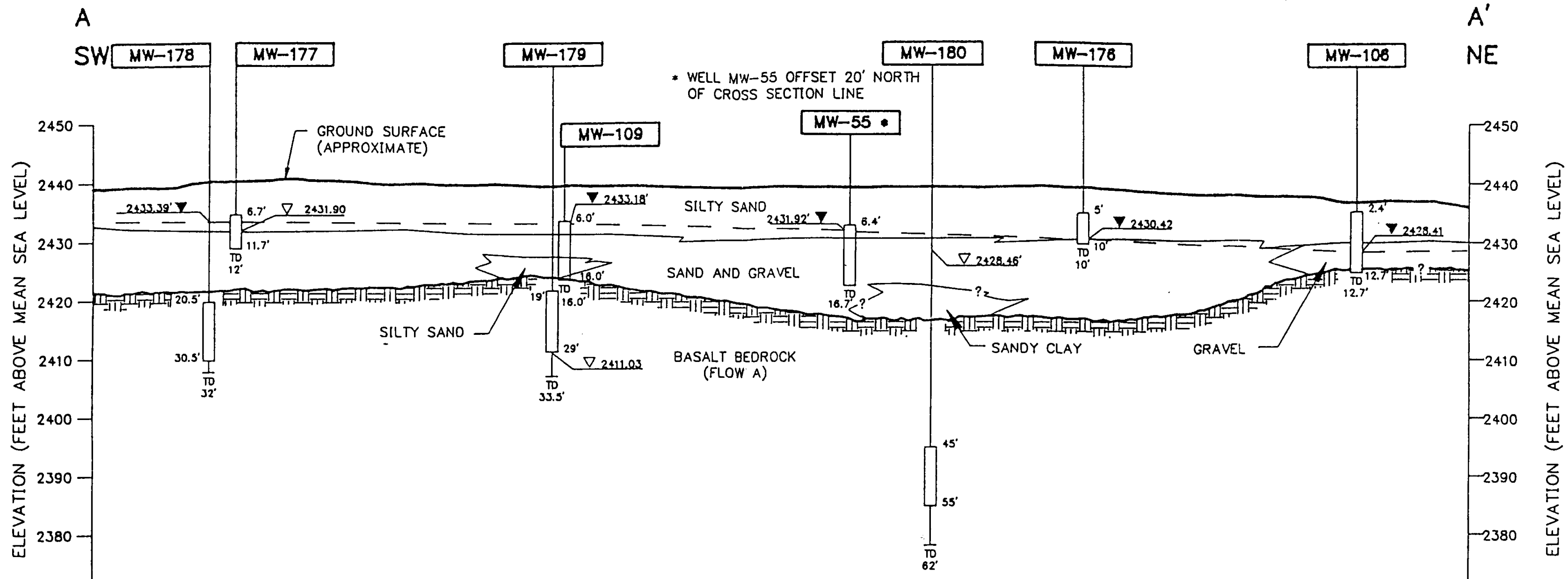
FIGURE 2.5

LOCATIONS OF SITE-SPECIFIC CROSS SECTIONS A-A' AND B-B'

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

Sources: Halliburton NUS, 1993; and ICF Technology Inc., 1995.



LEGEND

- MW-177 — WELL NUMBER
- GROUND SURFACE
- 15' — TOP OF SCREEN (FT. BELOW GROUND SURFACE)
- 2448.00' — WATER LEVEL ELEVATION
  - ▼ = WATER TABLE ELEVATION
  - ▽ = NON-WATER TABLE ELEVATION (CONFINED LAYER OR WELL NOT RECOVERED)
- 35' — BOTTOM OF SCREEN (FT. BELOW GROUND SURFACE)
- TD 45' — TOTAL DEPTH OF BORING (FT. BELOW GROUND SURFACE)
- TOP OF BEDROCK
- INFERRED LITHOLOGIC CONTACT
- WATER TABLE
- BEDROCK (BASALT A)

NOTES:

1. WATER LEVELS TAKEN 04/02/92
2. ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

0 20 40
VERTICAL SCALE IN FEET

0 100 200
HORIZONTAL SCALE IN FEET

VERTICAL EXAGGERATION 5:1

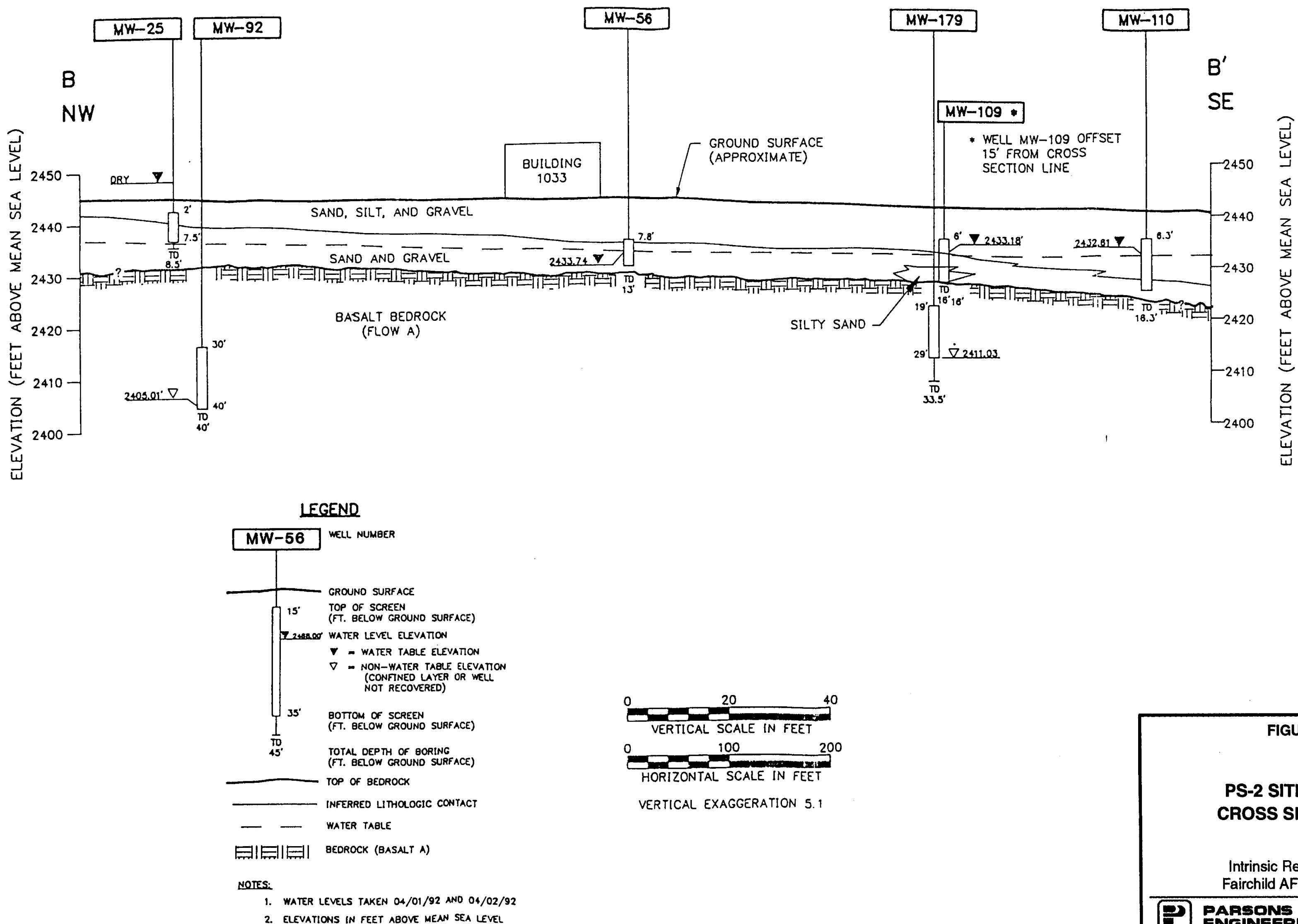
Sources: Halliburton NUS, 1993.

FIGURE 2.6

PS-2 SITE-SPECIFIC CROSS SECTION A-A'

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.



Sources: Halliburton NUS, 1993.

FIGURE 2.7

PS-2 SITE-SPECIFIC CROSS SECTION B-B'

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.

TABLE 2.1
SUMMARY OF WELL INSTALLATION DETAILS AND GROUNDWATER ELEVATION DATA, SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Well Identification	Sampling Event or Date	PVC Casing Size (inches)	Depth to Bottom of Well (feet bgs)	Screened Interval (feet bgs)	Elevation Top of PVC (feet amsl)	Ground Elevation (feet amsl)	Groundwater Elevation (feet amsl)	Source [a/]
MW-55	1988	2	16.6	6.35-16.60	NA [b/]	NA	NA	4
	11/17/92	2	16.19		2,439.36	2,439.72	2,431.66	3
	4/29/93	2	16.19		2,439.36	2,439.72	2,432.48	3
	7/27/93	2	16.19		2,439.36	2,439.72	2,432.16	3
	10/5/93	2	16.19		2,439.36	2,439.72	2,431.22	3
	2/8/94	2	16.19		2,439.36	2,439.72	2,431.82	3
	11/3/94	2	16.19		2,439.36	2,439.72	2,431.82	3
	04/04/95	2	15.95		2,439.36	2,439.72	2,432.78	2
MW-56	1988	2	13.0	7.75-13.00	NA	NA	NA	4
	11/17/92	2	12.70		2,442.18	2,442.55	2,433.39	3
	7/27/93	2	12.70		2,442.18	2,442.55	2,434.10	3
	10/5/93	2	12.70		2,442.18	2,442.55	2,433.11	3
	2/8/94	2	12.70		2,442.18	2,442.55	2,433.70	3
	5/5/94	2	12.70		2,442.18	2,442.55	2,433.86	3
	8/3/94	2	12.70		2,442.18	2,442.55	2,433.53	3
	11/3/94	2	12.70		2,442.18	2,442.55	2,434.00	3
	04/04/95	2	12.55		2,442.18	2,442.55	2,434.64	2
MW-105	1988	2	17.72	7.47-17.72	NA	NA	NA	4
	11/17/92	2	15.26		2,434.95	2,435.37	2,428.54	3
	4/29/93	2	15.26		2,434.95	2,435.37	2,429.36	3
	7/27/93	2	15.26		2,434.95	2,435.37	2,429.08	3
	10/5/93	2	15.26		2,434.95	2,435.37	2,428.57	3
	2/8/94	2	15.26		2,434.95	2,435.37	2,428.80	3
	5/5/94	2	15.26		2,434.95	2,435.37	2,428.85	3
	8/3/94	2	15.26		2,434.95	2,435.37	2,428.50	3
	11/3/94	2	15.26		2,434.95	2,435.37	2,428.65	3
MW-106	1988	2	12.69	2.44-12.69	NA	NA	NA	4
MW-109	1988	2	15.99	5.99-15.99	NA	NA	NA	4
	11/17/92	2	14.95		2,440.39	2,440.79	2,433.12	3
	4/29/93	2	14.95		2,440.39	2,440.79	2,433.88	3
	7/27/93	2	14.95		2,440.39	2,440.79	2,433.68	3
	10/5/93	2	14.95		2,440.39	2,440.79	2,432.63	3
	2/8/94	2	14.95		2,440.39	2,440.79	2,432.77	3
	5/4/94	2	14.95		2,440.39	2,440.79	2,433.08	3

TABLE 2.1 (Continued)
SUMMARY OF WELL INSTALLATION DETAILS AND GROUNDWATER ELEVATION DATA, SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

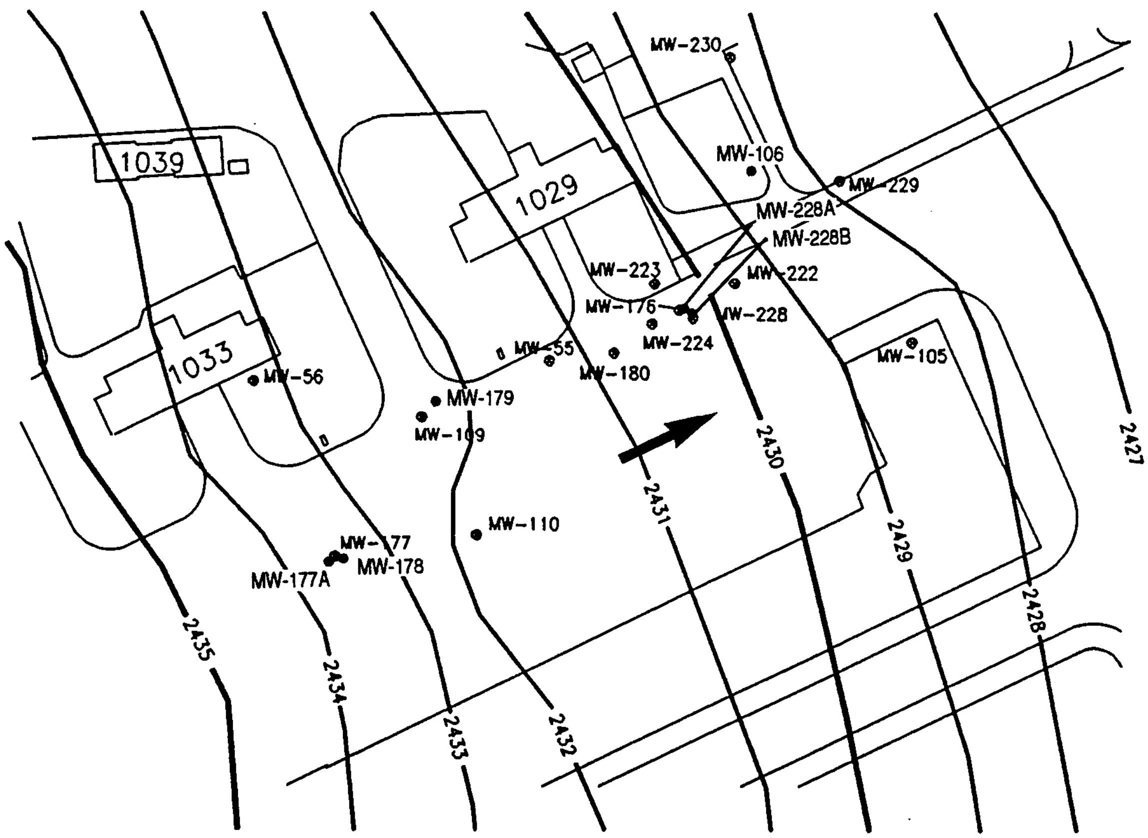
Well Identification	Sampling Event or Date	PVC Casing Size (inches)	Depth to Bottom of Well (feet bgs)	Screened Interval (feet bgs)	Elevation Top of PVC (feet amsl)	Ground Elevation (feet amsl)	Groundwater Elevation (feet amsl)	Source [a/]
MW-109	11/3/94	2	14.95		2,440.39	2,440.79	2,432.34	3
	04/04/95	2	14.65		2,440.39	2,440.79	2,433.94	2
MW-110	1988	2	16.27	6.27-16.27				4
	11/17/92	2	14.57		2,440.56	2,440.82	2,432.38	3
	4/29/93	2	14.57		2,440.56	2,440.82	2,433.58	3
	7/27/93	2	14.57		2,440.56	2,440.82	2,432.96	3
	10/5/93	2	14.57		2,440.56	2,440.82	2,431.84	3
	2/8/94	2	14.57		2,440.56	2,440.82	2,432.44	3
	11/3/94	2	14.57		2,440.56	2,440.82	2,434.34	3
	04/04/95	2	14.35		2,440.56	2,440.82	2,433.76	2
MW-176	09/91-12/91	2	10.0	5-9	2,439.09	NA	NA	1
MW-177	09/91-12/91	2	12.0	6.7-11.7	2,440.70	NA	NA	1
MW-177A	1995	4	14.5	NA	NA	NA	NA	5
MW-178	09/91-12/91	4	32.0	20.5-30.5	2,440.61	NA	NA	1
	11/17/92	4	29.29		2,440.45	2,440.83	2,433.60	3
	4/29/93	4	29.29		2,440.45	2,440.83	2,433.32	3
	7/27/93	4	29.29		2,440.45	2,440.83	2,434.27	3
	10/5/93	4	29.29		2,440.45	2,440.83	2,433.76	3
	2/11/94	4	29.29		2,440.45	2,440.83	2,433.12	3
	5/4/94	4	29.29		2,440.45	2,440.83	2,433.55	3
	8/2/94	4	29.29		2,440.45	2,440.83	2,432.83	3
	11/15/94	4	29.29		2,440.45	2,440.83	2,415.14	3
	04/04/95	4	29.32		2,440.45	2,440.83	2,434.63	2
MW-179	09/91-12/91	4	33.5	20.5-30.5	2,440.59	NA	NA	1
	11/17/92	4	30.35		2,440.52	2,440.83	2,411.37	3
	4/29/93	4	30.35		2,440.52	2,440.83	2,440.51	3
	7/27/93	4	30.35		2,440.52	2,440.83	2,440.46	3
	10/5/93	4	30.35		2,440.52	2,440.83	2,440.46	3
	2/11/94	4	30.35		2,440.52	2,440.83	2,418.10	3
	8/2/94	4	30.35		2,440.52	2,440.83	2,414.47	3
	11/15/94	4	30.35		2,440.52	2,440.83	2,427.99	3
	04/04/95	4	30.25		2,440.52	2,440.83	2,416.92	2

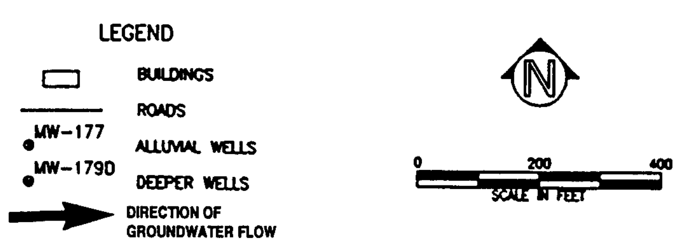
TABLE 2.1 (Concluded)
SUMMARY OF WELL INSTALLATION DETAILS AND GROUNDWATER ELEVATION DATA, SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Well Identification	Sampling Event or Date	PVC Casing Size (inches)	Depth to Bottom of Well (feet bgs)	Screened Interval (feet bgs)	Elevation Top of PVC (feet amsl)	Ground Elevation (feet amsl)	Groundwater Elevation (feet amsl)	Source [a/]
MW-180	09/91-12/91	4	62.0	45-55	2,439.20	NA	NA	1
	11/17/92	4	54.63		2,438.97	2,439.45	2,428.02	3
	4/29/93	4	54.63		2,438.97	2,439.45	2,429.39	3
	7/27/93	4	54.63		2,438.97	2,439.45	2,429.09	3
	10/5/93	4	54.63		2,438.97	2,439.45	2,428.33	3
	2/11/94	4	54.63		2,438.97	2,439.45	2,428.13	3
	5/4/94	4	54.63		2,438.97	2,439.45	2,428.15	3
	8/2/94	4	54.63		2,438.97	2,439.45	2,427.95	3
	04/04/95	4	54.55		2,438.97	2,439.45	2,429.81	2
MW-222	1995	4	15.48	NA	NA	NA	NA	5
MW-223	NA	4	NA	NA	NA	NA	NA	5
MW-224	1995	4	15	NA	NA	NA	NA	5
MW-228	1995	4	15.93	NA	NA	NA	NA	5
MW-228A	1995	4	20.04	NA	NA	NA	NA	5
MW-228B	1995	4	16	NA	NA	NA	NA	5
MW-229	11/18/94	4	15.52	NA	2,436.36	2,436.74	2,428.17	3
MW-230	11/22/94	4	11.45	NA	2,435.93	2,436.26	2,427.47	3

[a/] Sources:
1. HNUS, 1993.
2. ES&T and MWA, 1995.
3. ICF, 1995.
4. SAIC, 1988.
5. Verbal corrospondance with bioventing pilot test field personnel.

[b/] NA = Information not available.





Source: ICF Technology Inc., 1995.

FIGURE 2.8

GROUNDWATER SURFACE ELEVATIONS AT SITE PS-2 OCTOBER 1993

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

lower during August through November, and higher during April through July. Water table elevation fluctuations of up to 2 feet have been observed from November 1992 to November 1994 (ICF, 1995). Groundwater elevations measured in April 1992 indicate the hydraulic gradient in the vicinity of PS-2 steepens from 0.003 foot per foot (ft/ft) in the southwestern portion of the site to 0.006 ft/ft in the northeastern portion of the site (HNUS 1993). Similar gradients areis suggested by the 1993 groundwater elevation data presented in Figure 2.8 (ICF, 1995).

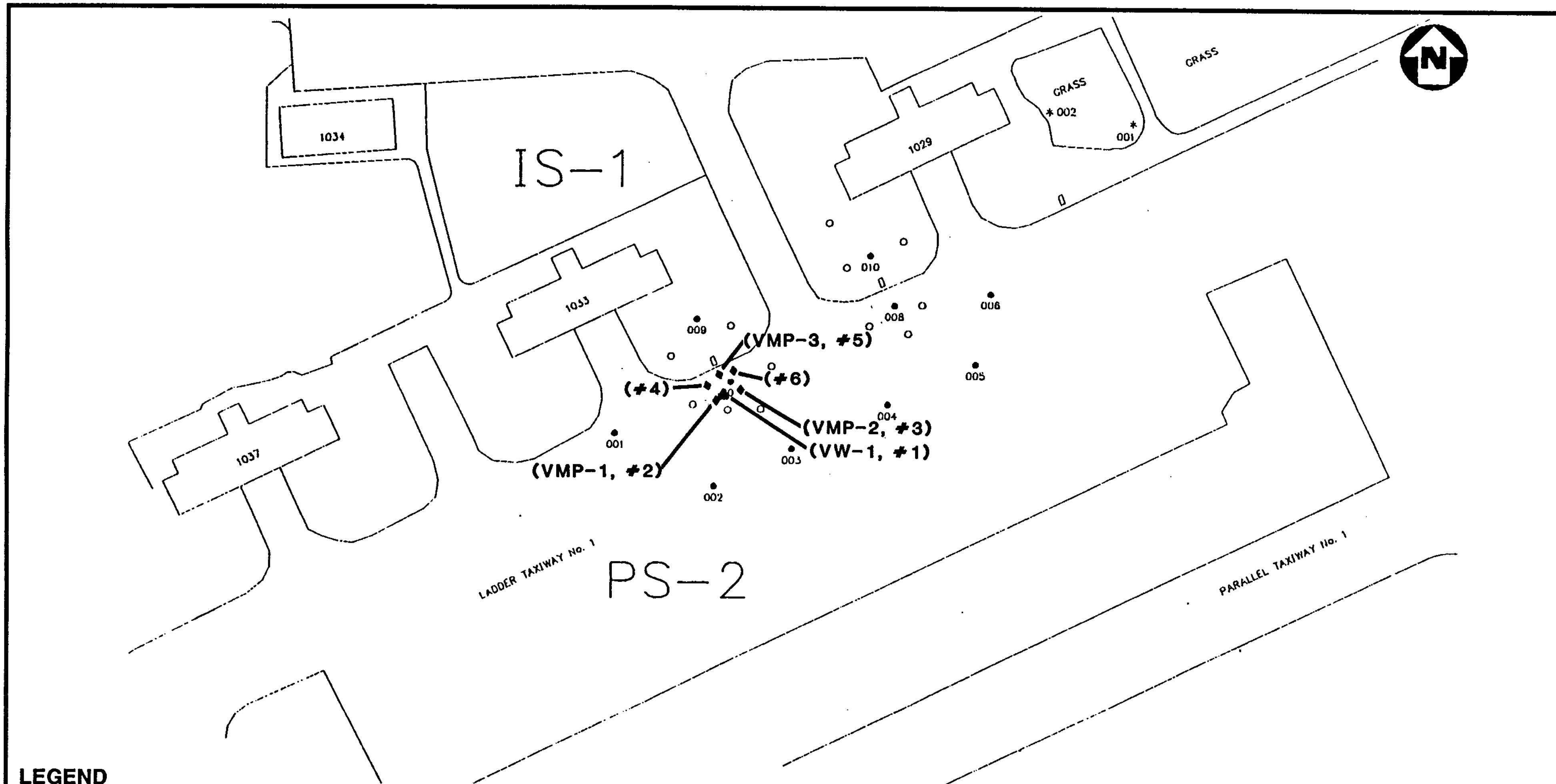
Three groundwater monitoring wells (MW-178, MW-179, and MW-180) were installed into the shallow basalt bedrock during previous investigations Figure 2.6). Groundwater data collected as part of the RI and the long-term monitoring program suggest that shallow bedrock groundwater elevations at MW-179 and MW-180 are consistently below groundwater elevations measured in surrounding alluvial wells. The groundwater elevation measured in MW-179 was nearly 5 feet lower than the groundwater elevation measured in the adjacent alluvial well MW-109, in November 1994. Additionally, the groundwater elevation measured in MW-180 was approximately 3.5 feet below the adjacent alluvial well MW-55, in February 1994. These data suggests vertical hydraulic gradients of 0.37 and 0.13 ft/ft in the vicinity of MW-179 and MW-180, respectively.

When pump testing was performed as part of the RI at alluvial well MW-55, drawdown was not observed in the two closest alluvial wells (MW-176 and MW-109). Using a semilog analysis (Theis 1935), estimates of transmissivity and hydraulic conductivity were calculated from residual drawdown observed in the pumping well, MW-55. Transmissivity was estimated at 212 square feet per day (ft^2/day) and hydraulic conductivity was estimated at 24 feet per day (ft/day) (HNUS, 1993). Another pump test was performed as part of the RI in the alluvial well, MW-67 at site PS-8, approximately 0.75/4 of a mile downgradient from PS-2. Again, drawdown was not measured in the closest observation, well and same analytical method was used to estimate the transmissivity and hydraulic conductivity from residual drawdown measurements collected from the pumping well. The estimated transmissivity and hydraulic conductivity from data collected at MW-67 were 2353 ft^2/day and 233 ft/day, respectively. The estimated values of transmissivity and hydraulic conductivity for the unconsolidated material at site PS-8 are significantly higher than the values estimated for the unconsolidated material at site PS-2. Other aquifer testing results were not available for review.

2.1.3 Summary of Analytical Data for PS-2

2.1.3.1 Soil Gas Sampling and Analytical Results

Both the SAIC (1990) site investigation and the ES (1994) bioventing pilot study included soil gas measurements. A quantitative soil gas survey was conducted in 1990 by SAIC. However, the results of this survey were not available in reports reviewed as part of the preparation of this work plan. Limited soil gas measurements also were collected as part of the bioventing pilot test at PS-2 (Figure 2.9). Analytical sampling of soil gas for BTEX and total volatile hydrocarbons (TVH) was performed. Results of initial soil gas sampling during the pilot test indicated that soil gas in the immediate vicinity of Defueling Pit 19 had elevated concentrations of BTEX and TVH, and very low concentrations of oxygen. Table 2.2 presents the analytical results of BTEX and



LEGEND

- ● RI SUBSURFACE SOIL BORING LOCATIONS 002 AND LOCATION NUMBERS
- ○ HISTORIC SUBSURFACE SOIL BORING LOCATIONS
- * RI SURFACE SOIL SAMPLE LOCATION AND SEQUENCE NUMBER (TABLE 2-4)
- (VMP-1,#2) ◆ (BIOVENTING VAPOR MONITORING POINT LOCATION, BIOVENTING BOREHOLE LOCATION)
- VW-1 ▲ (BIOVENTING VENT WELL LOCATION, BIOVENTING BOREHOLE LOCATION)

Sources: Halliburton NUS, 1993; ES, 1994.

FIGURE 2.9

LOCATIONS OF SOIL AND SOIL GAS SAMPLES COLLECTED DURING RI AND BIOVENTING PILOT TEST

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

TABLE 2.2
SOIL GAS CONCENTRATIONS MEASURED AT SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Sample Location - Depth (feet bgs) [a/]	TVH (ppmv) [b/]	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes, Total (ppmv)
VW1 - 7.5	110,000	150	< 3.7	24	130
VMP1-4	78,000	160	< 2.3	31	130
VMP3-7	170,000	400	93	42	190

Source: ES, 1994.

Note: Soil gas analyzed according to EPA Method TO-3.

[a/] bgs = below ground surface.

[b/] TVH = total volatile hydrocarbons measured as jet fuel; ppmv = parts per million, volume per volume.

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TVH soil gas samples collected during initial soil gas measurements for the bioventing pilot test. The elevated concentrations of soil gas BTEX and TVH indirectly suggest the presence of soil contamination in the area immediately surrounding defueling pit 19. Analysis of discrete soil samples collected during the installation of the VW and VMPs for the bioventing pilot test confirmed the presence of elevated soil concentrations of total petroleum hydrocarbons (TPH) and BTEX compounds (ES, 1994).

2.1.3.2 Soil Sampling and Analytical Results

Historical soil sampling data are available for sampling events that took place in 1986, 1988, 1990, 1991, 1993, and 1994. In 1986, 20 soil samples were collected from boreholes B-1 through B-10 at PS-2. Two years later, SAIC (1990)collected 6 additional soil samples during the installation of monitoring wells MW-55 and MW-56. In 1990, SAIC collected 8 additional soil samples during the installation of monitoring wells MW-105, MW-106, MW-109, and MW-110. In 1991, HNUS (1993) collected fifteen additional soil samples during the installation of soil borings 001 through 010. In 1993, ICF (1995) collected three soil samples during the installation of MW-229 and MW-230. Three additional samples were collected by ES (1994) in 1993 during the installation of the VW and VWPs for the bioventing pilot test. At a minimum, soil samples collected during these sampling events were analyzed for BTEX and TPH. Some soil sample were analyzed for additional contaminants; however, results reported for additional analytes are not of primary importance for completion of this TS and are not summarized in this work plan. Table 2.3 summarizes BTEX and TPH results for all soil samples collected during these sampling efforts. Locations of soil samples collected during the 1991 RI and the 1993 bioventing pilot test are shown on Figure 2.9. Locations and results of soil samples collected during the 1986, 1988, and 1990 SAIC investigations are presented on Figure 2.10.

Elevated BTEX and TPH concentrations were detected in several soil samples collected near defueling pit 19 and in one soil sample collected near defueling pit 18. Significant concentrations of BTEX and TPH in unsaturated soils appear to be limited to the soils in the vicinity of defueling pit 19. Vadose zone contamination at this location was detected by SAIC in 1986 and confirmed during the bioventing pilot test investigations in 1993. The maximum TPH concentration, 1,278 milligrams per kilogram (mg/kg), was measured in vadose soils during the 1986 investigation in borehole B-2 (SAIC, 1990). The maximum total BTEX contamination measured in unsaturated soils, 145.1 mg/kg, was detected during the 1993 bioventing pilot test investigation (ES, 1994) (Table 2.3). Unsaturated soil contamination in the region of defueling pit 18 is limited to isolated zones of TPH. A maximum TPH concentration of 180 mg/kg was detected by HNUS (1993) during the installation of borehole 5 in 1991. Soil sampling near MW-177 and MW-178 indicate that vadose soils in that area do not contain elevated concentrations of TPH or BTEX (HNUS, 1993). Notable concentrations of BTEX and TPH contamination appear to be limited to saturated soils immediately downgradient from defueling pit 19, and appear to coincide with areas of mobile LNAPL and elevated concentrations of BTEX and TPH in groundwater.

TABLE 2.3
SUMMARY OF SOIL ANALYTICAL DATA FOR SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Soil Boring Identification	Sampling Event or Date	Depth (feet bgs)[c/]	Benzene (mg/kg)[d/]	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Total BTEX (mg/kg)	TPH[a/] (mg/kg)	TRPH[b/] (mg/kg)	TPH-diesel (mg/kg)	TPH-Jet Fuel (mg/kg)	Unknown Hydrocarbons (mg/kg)	Source[e/]
B-1	1986	2.5-4.0	ND[f/]	1.8	3.4	19.5	24.7	ND	NA[g/]	NA	NA	NA	1
B-1	1986	5.0-5.5	2.4	ND	2.1	11.5	16	887	NA	NA	NA	NA	1
B-2	1986	3.5-5.0	ND	ND	2.7	16.5	19.2	1278	NA	NA	NA	NA	1
B-2	1986	3.5-5.0	ND	ND	2.1	8.9	11	525	NA	NA	NA	NA	1
B-2	1986	5.0-6.0	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
B-3	1986	2.5-4.0	ND	ND	1.8	9.9	11.7	1151	NA	NA	NA	NA	1
B-3	1986	4.0-5.5	ND	2.2	7.5	41.2	50.9	475	NA	NA	NA	NA	1
B-4	1986	2.5-4.0	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
B-4	1986	8.5-10.5	ND	2.1	ND	14.1	16.2	126	NA	NA	NA	NA	1
B-5	1986	4.0-5.5	ND	ND	ND	ND	ND	168	NA	NA	NA	NA	1
B-5	1986	8.5-10.0	ND	9.4	ND	92.1	101.5	628	NA	NA	NA	NA	1
B-6	1986	5.0-6.0	ND	ND	ND	ND	ND	370	NA	NA	NA	NA	1
B-6	1986	10.0-10.75	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
B-7	1986	5.0-6.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
B-7	1986	8.0-9.5	ND	3.9	10.8	46.5	61.2	786	NA	NA	NA	NA	1
B-8	1986	5.0-6.5	ND	ND	ND	ND	ND	466	NA	NA	NA	NA	1
B-8	1986	8.0-9.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
B-9	1986	5.0-6.5	ND	ND	ND	ND	ND	238	NA	NA	NA	NA	1
B-9	1986	5.0-6.5	ND	ND	ND	ND	ND	377	NA	NA	NA	NA	1
B-9	1986	8.0-9.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
B-10	1986	5.0-6.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
B-10	1986	8.0-9.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
PS2-BH1	1988	3.0-3.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-55	1988	3.5-4.0	ND	ND	ND	ND	ND	13	NA	NA	NA	NA	1
MW-55	1988	8.0-8.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-55	1988	13.0-13.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-56	1988	3.0-3.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-56	1988	8.0-8.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1

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TABLE 2.3 (Continued)
SUMMARY OF SOIL ANALYTICAL DATA FOR SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Soil Boring Identification	Sampling Event or Date	Depth (feet bgs)[c]	Benzene (mg/kg)[d]	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Total BTEX (mg/kg)	TPH[a] (mg/kg)	TRPH[b] (mg/kg)	TPH-diesel (mg/kg)	TPH-Jet Fuel (mg/kg)	Unknown Hydrocarbons (mg/kg)	Source
MW-56	1988	13.0-13.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-105	1990	7.0-8.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-106	1990	5.5-6.0	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-106	1990	10.5-11.0	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-106	1990	11.0-11.5	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-109	1990	6.0-6.5	ND	ND	1.0	3.2	4.2	460	NA	NA	NA	NA	1
MW-109	1990	10.5-11.0	ND	ND	ND	ND	ND	170	NA	NA	NA	NA	1
MW-110	190	5.5-6.0	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
MW-110	1990	10.5-11.0	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
001	1991	0-2	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
002	1991	2-6	ND	ND	ND	0.007	0.007	ND	NA	NA	NA	NA	1
002	1991	6-10	ND	ND	ND	0.014	0.014	ND	NA	NA	NA	NA	1
003	1991	0-2	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	1
003	1991	2-6	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
004	1991	Composite	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
005	1991	0-2	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
005	1991	2-6	ND	ND	ND	ND	ND	180	NA	NA	NA	NA	1
006	1991	2-6	0.006	ND	0.005	ND	0.011	ND	NA	NA	NA	NA	1
006	1991	6-10	ND	ND	1.7	4.7	6.4	ND	NA	NA	NA	NA	1
007	1991	Composite	ND	ND	ND	ND	ND	1,200	NA	NA	NA	NA	1
008	1991	2-6	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
009	1991	0-2	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
009	1991	0-6	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
010	1991	0-6	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
VW-1	1994	7.5	0.7	0.5	7.2	47	55.4	NA	250	NA	NA	NA	2
VMP-1	1994	4	4.1	ND	21	120	145.1	NA	280	NA	NA	NA	2
VMP-2	1994	4	0.14	ND	0.71	3.8	4.65	NA	980	NA	NA	NA	2

TABLE 2.3 (Concluded)
SUMMARY OF SOIL ANALYTICAL DATA FOR SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Soil Boring Identification	Sampling Event or Date	Depth (feet bgs)[c]	Benzene (mg/kg)[d]	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Total BTEX (mg/kg)	TPH[a] (mg/kg)	TRPH[b] (mg/kg)	TPH-diesel (mg/kg)	TPH-Jet Fuel (mg/kg)	Unknown Hydrocarbons (mg/kg)	Source
MW-229	1994	5.5-6.0	ND	ND	ND	ND	ND	NA	NA	ND	ND	ND	3
MW-229	1994	8.0-9.0	ND	ND	ND	ND	ND	NA	NA	ND	ND	850	3
MW-230	1994	7.0-8.0	ND	ND	ND	ND	ND	NA	NA	ND	ND	800	3
MW-230	1994	7.0-8.0	ND	ND	ND	ND	ND	NA	NA	ND	ND	ND	3

Notes:

[a] TPH = Total Petroleum Hydrocarbons

[b] TRPH = Total Recoverable Petroleum Hydrocarbons

[c] feet bgs = feet below ground surface

[d] mg/kg = milligrams per kilogram

[e] Sources:
1. HNUS, 1993
2. ES, 1994.
3. ICF, 1995.

[f] ND = Not detected.

[g] NA = Not analyzed.

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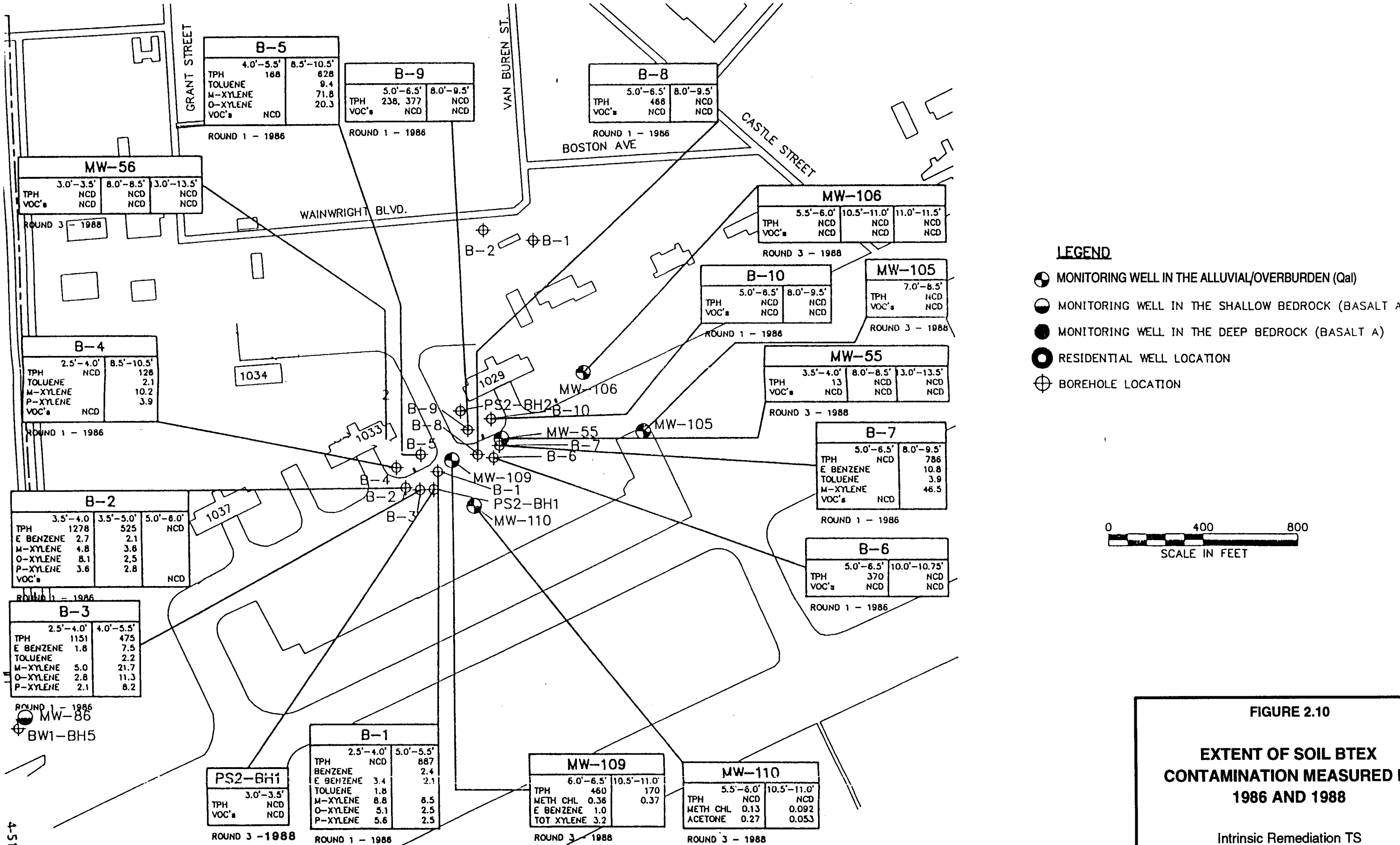


NOTE: UNITS ARE IN mg/kg UNLESS SPECIFIED OTHERWISE

4-51

Sources: Halliburton NUS, 1993.

FIGURE 2.10

EXTENT OF SOIL BTEX CONTAMINATION MEASURED IN 1986 AND 1988

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.

2.1.3.3 Groundwater Sampling and Analytical Results

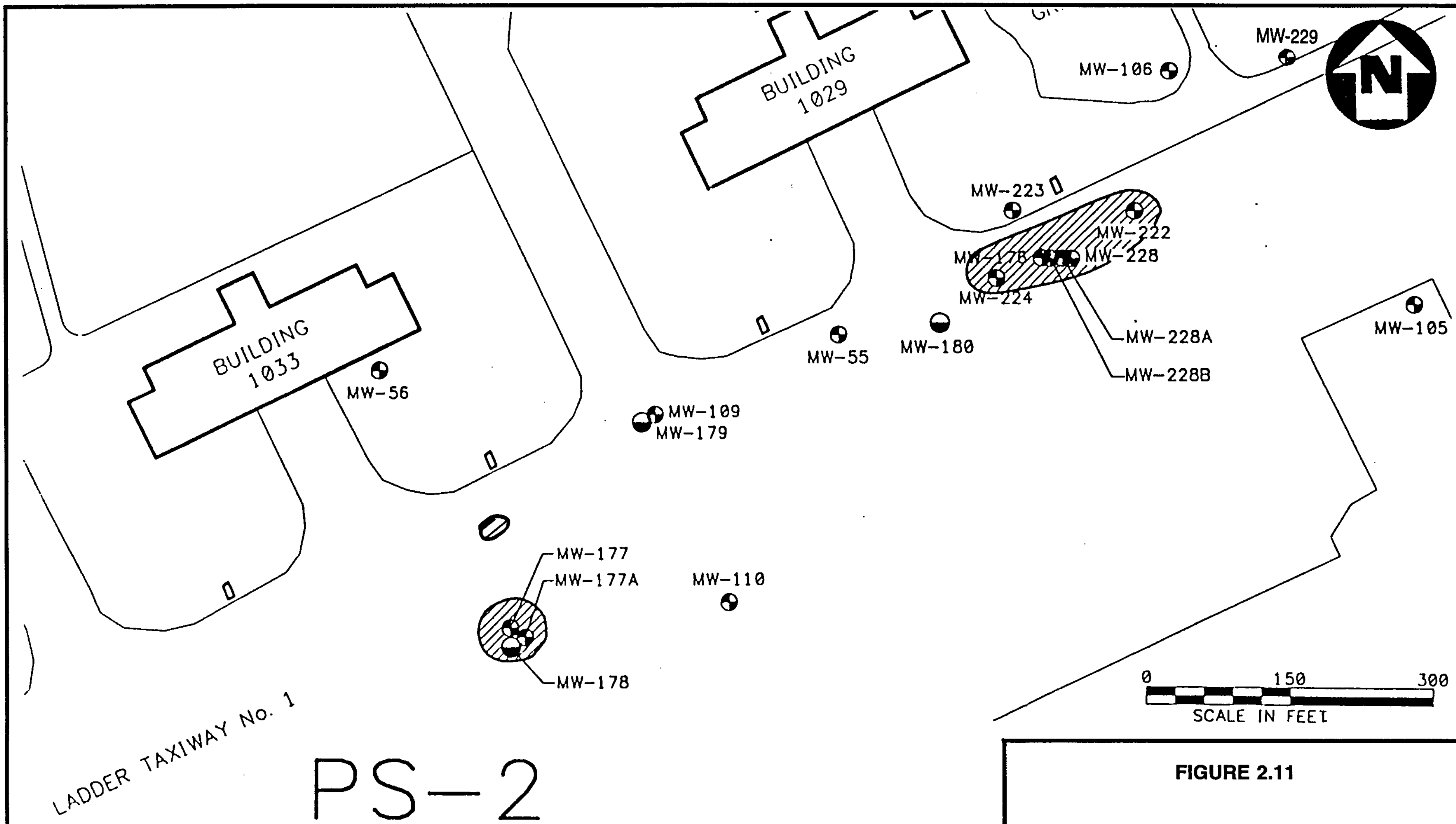
A total of 20 monitoring wells have been installed at PS-2. SAIC (1990) installed 2 wells (MW-55 and MW-56) in 1988, and four additional wells (MW-105, MW-106, MW-109, and MW-110) in 1990. Five wells (MW-176, MW-177, MW-178, MW-179, and MW-180) were installed during the RI in 1992 (HNUS, 1993). Limited information regarding installation of the floating free product recovery TS wells (MW-177A, MW-222, MW-223, MW-224, MW-228, MW-228A, and MW-228B) were available for inclusion in this work plan. However, it is believed that the Floating Fee Product TS wells were installed in 1993. Two additional monitoring wells (MW-229 and MW230) were installed in 1994 (ICF, 1995). Available well construction details are presented in Table 2.1. All of the monitoring wells at PS-2 are in front of Buildings 1029 and 1033 or adjacent to Taxiway No. 1 (Figure 2.11). Monitoring wells MW-178, MW-179, and MW-180 are screened in the shallow bedrock while all other monitoring wells are screened in the unconsolidated alluvial material.

Groundwater quality data have been collected from PS-2 wells on at least an annual basis since 1989 as part of long-term monitoring activities at the site. BTEX and TPH results for all site investigations and available ground water sampling events are presented in Table 2.4.

Mobile LNAPL at PS-2 has been observed near MW-176 and near MW-177 (Figure 2.11). Mobile LNAPL was first documented at PS-2 in MW-176 and MW-177 during the 1993 RI investigation. Product thicknesses in 1992 were 0.18 inch and 1.44 inches at MW-176 and MW-177, respectively (HNUS, 1993). The zones of the mobile LNAPL shown in Figure 2.11 appear to be physically and chemically different from each other. The LNAPL near MW-176 is amber in color, while the LNAPL collected from MW-177 is black (HNUS, 1993). Chemical analysis of the LNAPL present at the site was not been reported in available site investigation reports. However, groundwater samples collected from wells near MW-176 contained a significantly higher mass fraction of benzene than groundwater samples collected from wells near MW-177. This suggests that the two mobile LNAPL plumes are from two different sources, and that the product found in MW-177 is more weathered than the product found in MW-176. Additionally, mobile LNAPL was detected near defueling pit 19 during the installation of VMP-1 (ES, 1994). However, the thickness and physical characteristics of the free product detected at this location have not been documented.

Elevated concentrations of BTEX in groundwater correspond with regions of mobile LNAPL at PS-2 (Figures 2.11 and 2.12). Total BTEX concentrations in excess of 100 micrograms per liter (μg/L) were detected in groundwater samples collected from MW-177, MW-109, MW-176, MW-222, MW-224, MW-228 and MW-228A (Table 2.4). All of these sampling locations are within regions where mobile LNAPL has been observed. The leading edge of the BTEX plume appears to have higher concentrations of benzene than of the other BTEX compounds (Figure 2.13). This is consistent with theoretical predictions indicating that benzene is the most mobile of the other BTEX compounds.

Low BTEX concentrations have been detected in groundwater samples collected from MW-178, which is screened in the shallow bedrock. Although, early samples collected from MW-178 exhibited low concentrations of BTEX and TPH



LEGEND

- REFUELING/DEFUELING PIT
- ALLUVIAL/OVERBURDEN MONITORING WELL
- SHALLOW DEDROCK MONITORING WELL
- ESTIMATED AREA OF MOBILE LNAPL

Source: Halliburton NUS, 1994.

FIGURE 2.11

EXTENT OF MOBILE LNAPL AT PS-2

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

TABLE 2.4
SUMMARY OF GROUNDWATER ANALYTICAL DATA FOR SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Location	Sampling Event or Date	Benzene (μg/L) [a]	Toluene (μg/L)	Ethylbenzene (μg/L)	Total Xylenes (μg/L)	Total BTEX (μg/L)	TPH (mg/L) [b]	TPH-gas (mg/L)	TPH-diesel (mg/L)	TPH-Jet Fuel (mg/L)	Unknown Hydrocarbons (mg/L)	Source [c]
MW-55	11/88	15	ND [d]	19	72	106	6.8	NA [e]	NA	NA	NA	1
	11/88	14	ND	21	72	107	0.6	NA	NA	NA	NA	1
	04/89	29	ND	35	150	214	0.6	NA	NA	NA	NA	1
	06/90	12	ND	12	ND	24	2	NA	NA	NA	NA	1
	08/90	53	ND	180	270	503	ND	NA	NA	NA	NA	1
	11/91	10.00	ND	13.00	25.00	48.00	< 0.2	NA	NA	NA	NA	1
	11/91	41.00	ND	59.00	130.00	230.00	0.5	NA	NA	NA	NA	1
	08/94	20	5 U	31	13	69	NA	0.89 J [f]	0.20	NA	NA	4
	11/94	8	5 U [g]	12	10 UJ [h]	35	NA	0.12	0.25 U	NA	NA	3
	11/94	11.0	1.0 U	18	1.0 U	31	NA	NA	NA	NA	NA	5
	11/94	10	1.0 U	18	1.0 U	30	NA	NA	NA	NA	NA	5
	04/95	16	ND	19	1.7	36.7	NA	NA	NA	NA	NA	2
MW-56	11/88	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
	04/89	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
	06/90	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
	08/90	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
	11/91	ND	ND	ND	ND	ND	< 0.2	NA	NA	NA	NA	1
	11/94	0.50 U	1.0 U	1.0 U	1.0 U	3.5 U	NA	NA	NA	NA	NA	5
	11/94	0.50 U	1.0 U	1.0 U	1.0 U	3.5 U	NA	NA	NA	NA	NA	5
MW-105	02/91	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
	04/91	ND	ND	ND	ND	ND	< 0.20	NA	NA	NA	NA	1
	11/94	0.50	1.0 U	1.0 U	1.0 U	3.5	NA	NA	NA	NA	NA	5

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TABLE 2.4 (Continued)
SUMMARY OF GROUNDWATER ANALYTICAL DATA FOR SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Location	Sampling Event or Date	Benzene (µg/L) [a]	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	TPH (mg/L) [b]	TPH-gas (mg/L)	TPH-diesel (mg/L)	TPH-Jet Fuel (mg/L)	Unknown Hydrocarbons (mg/L)	Source [c]
MW-106	02/91	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
	04/91	ND	ND	ND	ND	ND	< 0.20	NA	NA	NA	NA	1
	11/91	ND	ND	5.00	12.00	17.00	< 0.2	NA	NA	NA	NA	1
MW-109	02/91	150	ND	530	1,200	1,880	16	NA	NA	NA	NA	1
	04/91	34	ND	ND	290	324	6.8	NA	NA	NA	NA	1
	11/91	40.00 J	ND	190.00 J	420.00 J	650.00 J	4.4	NA	NA	NA	NA	1
	11/91	40.00	ND	170.00	240.00	450.00	4.0	NA	NA	NA	NA	1
	11/94	12	5 U	550	935 UJ	1,502	NA	4.80	2.10	NA	NA	3
	11/94	10 U	20 U	530	780	1,340	NA	NA	NA	NA	NA	5
	11/94	10 U	20 U	380	670	1,080	NA	NA	NA	NA	NA	5
	04/95	23	2.2	160	224	409.2	NA	NA	3.9	NA	NA	2
MW-109A	04/95	21	1.2	120	152.6	294.8	NA	NA	5.3	NA	NA	2
MW-110	02/91	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	1
	04/91	ND	ND	ND	ND	ND	< 0.20	NA	NA	NA	NA	1
	08/94	5 U	5 U	5 U	10 U	25 U	NA	0.26 J	0.10 U	NA	NA	4
	11/94	5 U	5 U	5 U	10 U	25 U	NA	0.20	0.25 U	NA	NA	3
	11/94	2.7	2.5	1.0 U	26	32.2	NA	NA	NA	NA	NA	5
	11/94	1.8	1.3	1.0 U	22	26.1	NA	NA	NA	NA	NA	5
	04/95	2.2	ND	3.0	1.0	6.2	NA	NA	0.72	NA	NA	2

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TABLE 2.4 (Continued)
SUMMARY OF GROUNDWATER ANALYTICAL DATA FOR SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Location	Sampling Event or Date	Benzene (µg/L) [a]	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	TPH (mg/L) [b]	TPH-gas (mg/L)	TPH-diesel (mg/L)	TPH-Jet Fuel (mg/L)	Unknown Hydrocarbons (mg/L)	Source [c]
MW-176	11/91	2,600.00	ND	1,200.00	5,000.00	8,800.00	110	NA	NA	NA	NA	1
	08/94	1,200	2,500	580	4,500	8,780	NA	25.00 J	100.00	NA	NA	4
	11/94	2,100	500 U	2,400	11,500	16,500	NA	22.00	75.00	NA	NA	3
MW-177	11/91	240.00	ND	520.00	2,200.00	2,960.00	27	NA	NA	NA	NA	1
	08/94	120 U	120 U	590	2,520	3,350	NA	11.00 J	7.80 J	NA	NA	4
	11/94	100 U	100 U	420	2,000	2,620	NA	11.00	13.00 J	NA	NA	3
MW-177A	08/94	5 U	5 U	5 U	10 U	25 U	NA	0.36 J	0.10 U	NA	NA	4
	08/94	5 U	5 U	5 U	10 U	25 U	NA	0.55 J	0.10 U	NA	NA	4
	11/94	5	5 U	5 U	10 UJ	25	NA	0.27	0.25 U	NA	NA	3
MW-178	11/91	7.00	ND	11.00	40.00	58.00	< 0.2	NA	NA	NA	NA	1
	11/91	7.00	ND	10.00	38.00	55.00	< 0.2	NA	NA	NA	NA	1
	11/94	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	NA	NA	NA	NA	NA	5
	04/95	ND	ND	ND	1.3	1.3	NA	NA	0.27	NA	NA	2
MW-179	11/94	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	NA	NA	NA	NA	NA	5
	04/95	NA	NA	NA	NA	NA	NA	NA	0.27	NA	NA	2
MW-180	11/91	ND	ND	ND	ND	ND	< 0.2	NA	NA	NA	NA	1
	11/94	0.50 U	1.0 U	1.0 U	1.0 U	3.5 U	NA	NA	NA	NA	NA	5
	04/95	ND	ND	ND	1.7	1.7	NA	NA	NA	NA	NA	2
MW-222	08/94	44	5 U	14	14	77	NA	6.905	1.00	NA	NA	4
	11/94	79	5 U	26	10 U	120	NA	8.50	0.38	NA	NA	3

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TABLE 2.4 (Concluded)
SUMMARY OF GROUNDWATER ANALYTICAL DATA FOR SITE PS-2
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Location	Sampling Event or Date	Benzene (µg/L) [a]	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	TPH (mg/L) [b]	TPH-gas (mg/L)	TPH-diesel (mg/L)	TPH-Jet Fuel (mg/L)	Unknown Hydrocarbons (mg/L)	Source [c]
MW-224	08/94	11	5 U	94	43	153	NA	1.40 J	0.83 J	NA	NA	4
	11/94	52	5 U	140	185	382	NA	1.90	1.10	NA	NA	3
MW-228	08/94	220	120 U	240	1,090	1,670	NA	25.00 J	100.00 J	NA	NA	4
	11/94	490	83 U	420	2,083	3,076	NA	31.00	54.00	NA	NA	3
MW-228A	08/94	410	250 U	430	2,250	3,340	NA	490.00 J	190.00 J	NA	NA	4
	11/94	2,000	250 U	1,400	5,650	9,300	NA	45.00	110.00	NA	NA	3
MW-228B	08/94	67	5 U	67	197	336	NA	1.60 J	0.77	NA	NA	4
	08/94	66	5 U	68	187	326	NA	2.10 J	0.71	NA	NA	4
	11/94	28 J	5 U	22 J	82 UJ	137 UJ	NA	1.30	0.40	NA	NA	3
MW-229	11/94	3.2	3.9	21	7.4	35.5	NA	NA	0.50 U	0.50 U	0.87	5
MW-230	11/94	0.50 U	1.0 U	2.7	1.0 U	5.2	NA	NA	0.50 U	0.50 U	0.50	5
	11/94	0.50 U	1.0 U	3.7	1.0 U	6.2	NA	NA	0.50 U	0.50 U	0.53	5

a/ µg/L = micrograms per liter.
b/ TPH = total petroleum hydrocarbons; mg/L = milligrams per liter.
c/ Sources:
1. HNUS, 1993.
2. ES&T AND MWA, 1995.
3. HNUS, 1995b.
4. HNUS, 1994.
5. ICF, 1995.
d/ ND = not detected.
e/ NA = not analyzed.
f/ J = estimated value.
h/ U = analyte not detected above method detection limit.
i/ UJ = estimated not detected.

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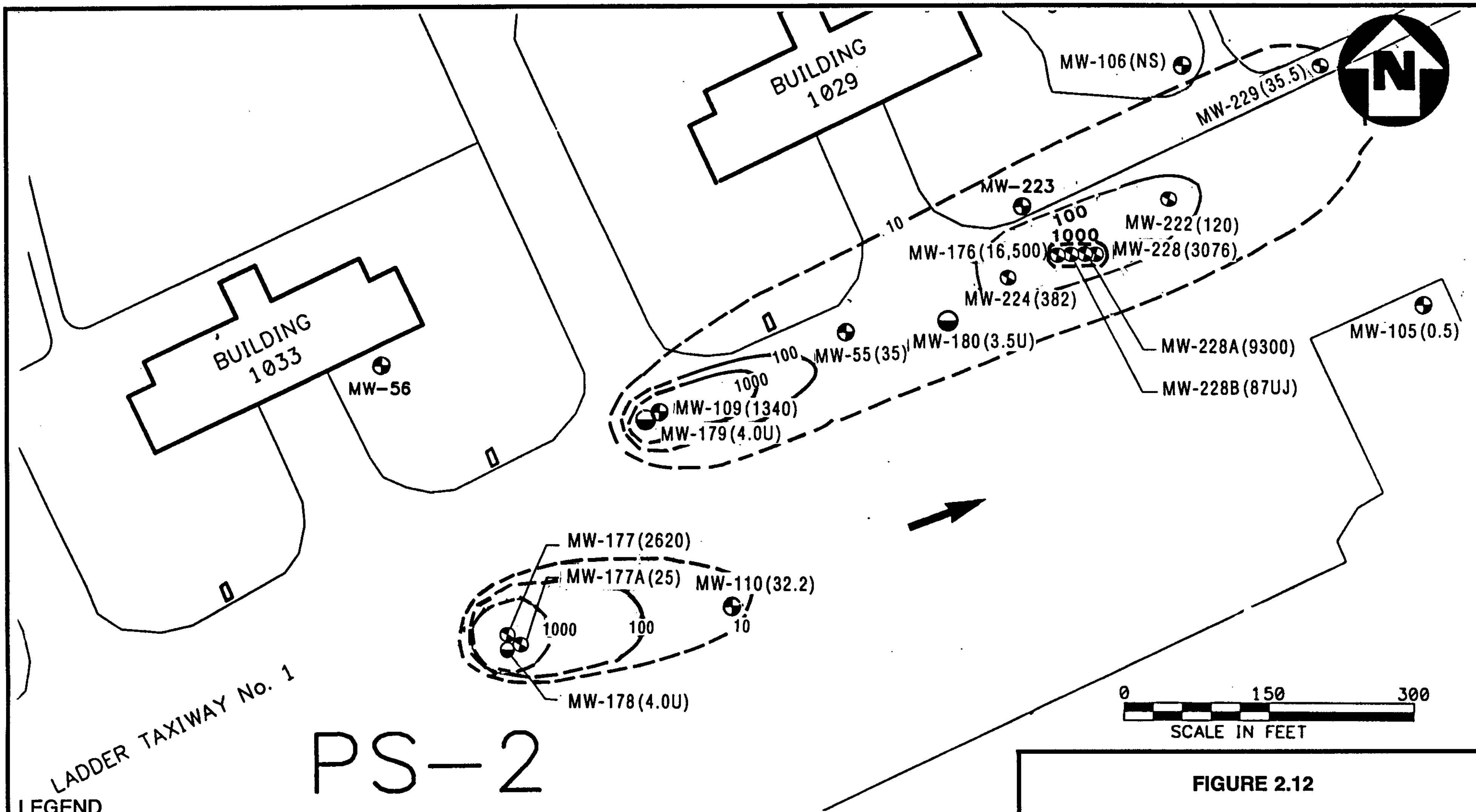


LEGEND

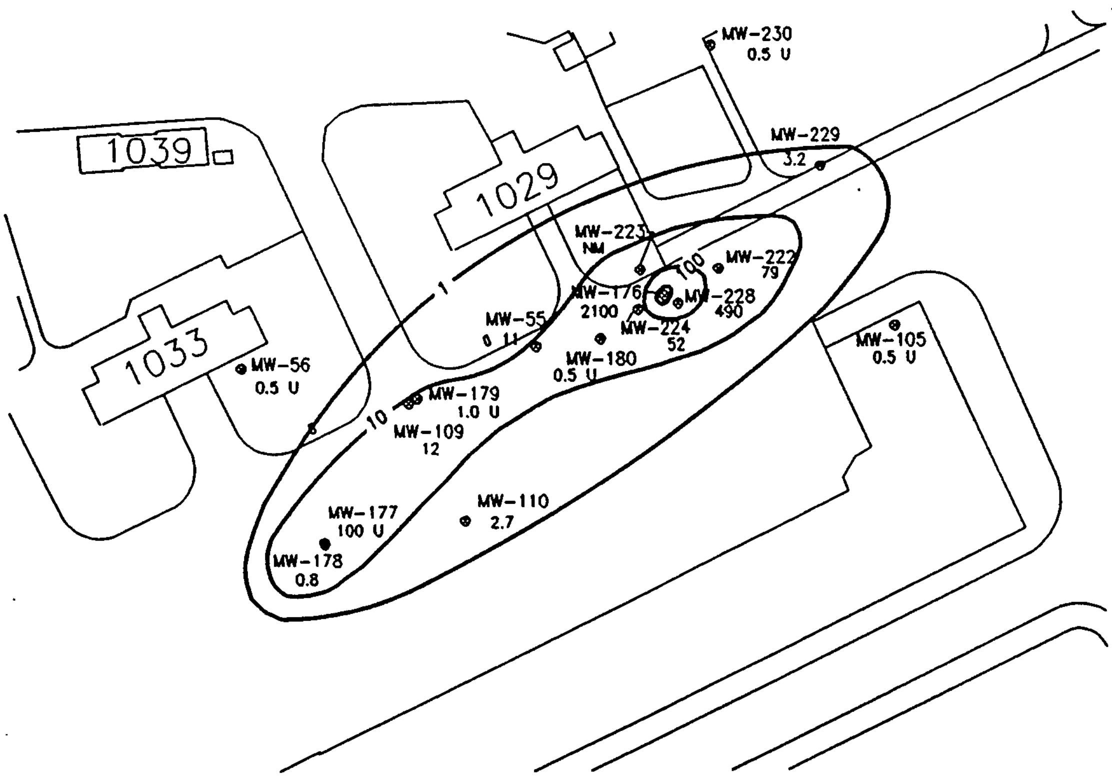
▭	REFUELING/DEFUELING PIT	(25)	TOTAL BTEX CONCENTRATION (µg/l)
⊕	ALLUVIAL/OVERBURDEN MONITORING WELL	U	BTEX NOT DETECTED ABOVE MITHOD DETECTION LIMITS
◒	SHALLOW BEDROCK MONITORING WELL	J	ESTIMATED VALUE
— 100 —	ESTIMATED LINE OF EQUAL BTEX CONCENTRATION (µg/l) (DASHED WHEERRED).	NS	NOT SAMPLED
		→	DIRECTION OF GROUNDWATER FLOW

FIGURE 2.12

EXTENT OF DISSOLVED TOTAL BTEX CONTAMINATION AT PS-2 NOVEMBER 1994

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



LEGEND

BUILDINGS

ROADS

MW-178 ALLUVIAL WELLS

NM NOT MEASURED

U NON-DETECT, VALUE REPRESENTS DETECTION LIMIT

CONCENTRATIONS IN ug/L

NOTE: DATA FROM EACH WELL IS FROM ITS MOST RECENT SAMPLING EVENT (SEE TABLE 4-4).

N

0 200 400
SCALE IN FEET

Sources: ICF Technology Inc., 1995.

FIGURE 2.13

EXTENT OF BENZENE CONTAMINATION IN GROUNDWATER NOVEMBER, 1994

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

contamination, more recent results of groundwater sampling at MW-178 indicate that BTEX contamination is declining at this location. BTEX and TPH have not been detected in groundwater samples collected from MW-179 or MW-180. Currently, no shallow bedrock wells have been installed beneath the body of free product detected near MW-176.

The data suggest that two separate and distinct dissolved BTEX plumes are present at PS-2. The two regions of mobile LNAPL detected at the site appear to be acting as continuing sources of BTEX contamination for the each of the dissolved BTEX plumes. Elevated concentrations of BTEX are not found in unsaturated soil samples collected above the dissolved BTEX plumes. Current analytical data also suggests that significant downward vertical migration in groundwater does not appear to be occurring at PS-2, although more data are required to confirm that such migration is not occurring near MW-176. Currently, the areal extents of the dissolved BTEX plumes at PS-2 are not fully delineated. Additional data will be necessary to fully delineate the dissolved plumes in the downgradient and crossgradient directions. Upgradient groundwater sampling also will be performed in order to measure geochemical data essential for evaluating intrinsic remediation at PS-2. Additionally, the poor correlation of reported source areas to current dissolved plume locations may require that more soil and groundwater data be collected to acquire a better understanding of plume dynamics.

2.2 DEVELOPMENT OF CONCEPTUAL SITE MODEL

A CSM is a three-dimensional representation of a site's hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. A CSM is developed to provide an understanding of the mechanisms controlling contaminant fate and transport and to identify additional data requirements. The model describes known and suspected sources of contamination, types of contamination, affected media, and contaminant migration pathways. The model also provides a foundation for formulating decisions regarding additional data collection activities and potential remedial actions. The CSM for PS-2 will be used to aid in selecting additional data collection points and to identify appropriate data needs for modeling and hydrocarbon degradation using groundwater flow and solute transport models.

Successful conceptual model development involves:

- Defining the problem to be solved;
- Integrating available data, including
  - Local geologic and topographic data,
  - Hydraulic data,
  - Site stratigraphic data,
  - Contaminant concentration and distribution data;
- Evaluating contaminant fate and transport characteristics;

- Identifying contaminant migration pathways;

- Identifying potential receptor and receptor exposure points; and

- Determining additional data requirements.

2.2.1 Intrinsic Remediation and Groundwater Flow and Solute Transport Models

After a site has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and whether any pathway for exposure of human or ecological receptors to site contaminants may be complete. Groundwater flow and solute transport models have proven useful for predicting BTEX plume migration and contaminant attenuation by natural biodegradation. Analytical solute transport models and the Bioplume II numerical model (Rifai *et al.*, 1988) can be used to evaluate critical groundwater fate and transport processes that may be involved in some of the migration pathways to human and ecological receptors. Quantitative fate and transport analyses can be used to determine what level and extent of remediation is required.

An accurate estimate of the potential for natural biodegradation of BTEX compounds in groundwater is important to consider when determining whether fuel hydrocarbon contamination presents a substantial threat to human health and the environment, and when deciding what type of remedial alternative will be most cost-effective in eliminating or abating these threats. Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons (Lee, 1988). This process occurs naturally when sufficient oxygen (or other electron acceptors) and nutrients are available in the groundwater. The rate of natural biodegradation is generally limited by the lack of oxygen (or other electron acceptors) rather than by the lack of nutrients such as nitrogen or phosphorus. The supply of oxygen to unsaturated soil is constantly renewed by the vertical diffusion from the atmosphere. The supply of oxygen to a shallow, fuel-contaminated aquifer is constantly renewed by the influx of oxygenated, upgradient flow and recharge from precipitation and by the vertical diffusion of oxygen from the unsaturated soil zone into the groundwater (Borden and Bedient, 1986). The rate of natural biodegradation in unsaturated soil and shallow aquifers is largely dependent upon the rates at which oxygen and other electron acceptors enter the contaminated media.

2.2.2 Biodegradation of Dissolved BTEX Contamination

The positive effect of natural attenuation processes (e.g., advection, dispersion, sorption, and biodegradation) on reducing the actual mass of fuel-related contamination dissolved in groundwater has been termed intrinsic remediation. Advantages of intrinsic remediation include: (1) contaminants are transformed to innocuous byproducts (e.g., carbon dioxide and water), not just transferred to another phase or location within the environment; (2) current pump-and-treat technologies are energy-intensive and generally not as effective in reducing residual contamination; (3) the process is nonintrusive and allows continuing use of infrastructure during remediation; (4) current engineered remedial technologies may pose a greater risk to potential receptors than intrinsic remediation because contaminants may be transferred into the

atmosphere during remediation activities; and (5) intrinsic remediation is far less costly than conventional, engineered remedial technologies.

To estimate the impact of natural attenuation on the fate and transport of BTEX compounds dissolved in groundwater at a site, two important lines of evidence must be demonstrated (Wiedemeier *et al.*, 1995). The first is a documented loss of contaminants at the field scale. Dissolved concentrations of biologically recalcitrant tracers found in most fuel contamination are used in conjunction with aquifer hydrogeologic parameters, such as groundwater seepage velocity and dilution, to demonstrate that a reduction in contaminant mass is occurring at the site. The second line of evidence involves the use of chemical analytical data in mass-balance calculations to show that areas with BTEX contamination can be correlated to areas with depleted electron acceptor (e.g., oxygen, nitrate, and sulfate) concentrations and increases in metabolic fuel degradation byproduct concentrations (e.g., methane and ferrous iron). With this site-specific information, groundwater flow and solute transport models can be used to simulate the fate and transport of dissolved BTEX compounds under the influence of natural attenuation.

Analytical and numerical models are available for modeling the fate and transport of fuel hydrocarbons under the influence of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. Analytical models may be used in conjunction with the Bioplume II numerical model, as appropriate. The Bioplume II numerical model is based upon the USGS two-dimensional (2-D) solute transport model, which has been modified to include a biodegradation component that is activated by a superimposed plume of dissolved oxygen. Bioplume II solves the USGS 2-D solute equation twice, once for hydrocarbon concentrations in the groundwater and once for a dissolved oxygen plume. The two plumes are then combined using superimposition at every particle move to simulate biological reactions between fuel products and oxygen. As appropriate, biodegradation of contaminants by anaerobic processes is simulated using a first-order anaerobic decay rate.

The analytical solute transport models are derived from advection-dispersion equations given by Wexler (1992) and Van Genuchten and Alves (1982). These models provide exact, closed-form solutions and are appropriately used for relatively simple hydrogeologic systems that are homogeneous and isotropic. Each model is capable of simulating advection, dispersion, sorption, and biodegradation (or any first-order decay process). These models can simulate continuous or decaying sources. A continuous source model is useful for determination of the worst-case distribution of the dissolved contaminant plume. A decaying source model is useful for simulating source removal scenarios, including natural weathering processes and engineered solutions.

2.2.3 Initial Conceptual Site Model

Site PS-2 geologic data were previously integrated to produce two geologic cross-sections of the site. Cross sections A - A' and B - B' (Figures 2.6 and 2.7) show the dominant hydrostratigraphic units present at the site and the elevation of the water table. Figure 2.8 is a groundwater surface map prepared using October 1993 groundwater elevation data (ICF, 1995).

The surface of the groundwater table is present at approximately 6 to 9 feet bgs in the silty and gravelly sand, and gravel deposits in the vicinity of the site. Groundwater also occurs in shallow bedrock, which is present at 18 to 25 feet bgs. Groundwater flow in the alluvium is to the east-northeast, with an average gradient of 0.0045 ft/ft. On the basis of the available data, Parsons ES will model the site as an unconfined, fine- to coarse-grained sand and gravel aquifer. This CSM will be modified as necessary as additional site hydrogeologic data become available. Vertical migration of site contaminants in groundwater will be further investigated in the area of MW-176.

Mobile LNAPL is present at PS-2, and it will be necessary to use the fuel/water partitioning models of Bruce *et al.* (1991) or Cline *et al.* (1991) to provide a conservative source term to model the partitioning of BTEX from the mobile LNAPL into the groundwater. In order to use one of these models, samples of free product will be collected and analyzed for mass fraction of BTEX. Parsons ES also will collect additional groundwater samples from immediately below the LNAPL layer. Figure 2.11 shows the locations of the mobile LNAPL, and Figure 2.12 shows the extent of BTEX groundwater contamination at the site. Information from these maps and historical soil contamination data for the site (Table 2.3) will be used to select the locations of new monitoring wells to fully define the extents of the LNAPL and the dissolved BTEX plumes at PS-2.

Because of it solubility and relative toxicity benzene is the primary chemical of interest in groundwater at PS-2. However, the synergistic effects of all of the BTEX compound on attenuation rates make site data on all of the BTEX compounds important. Therefore, all of the BTEX compound will be the primary focus of this intrinsic remediation TS. The Bioplume II model will be used to simulate the degradation of these chemicals at PS-2 and to predict the concentrations and extent of the contaminant plumes in the groundwater over time.

Dissolved BTEX at the site are expected to leach from contaminated soils containing fuel residuals, to dissolve from mobile LNAPL into the groundwater, and to migrate downgradient as a dissolved contaminant plume. In addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, and adsorption), these dissolved contaminants will likely be removed from the groundwater system by destructive attenuation mechanisms, such as biodegradation. The effects of these fate and transport processes on the dissolved groundwater plume will be investigated using the quantitative groundwater analytical data and the solute transport models. Data collection and analysis requirements are discussed in Section 3 of this work plan.

2.2.4 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as groundwater discharge points and subsurface utility corridors (artificial conduits) will be identified during the field work phase of this project. The primary potential migration path for contaminants at PS-2 is from the residual LNAPL in contaminated soils and mobile LNAPL at the site into the groundwater, and from the groundwater to potential receptors via ingestion or incidental contact.

Shallow groundwater beneath PS-2 flows toward the east-northeast. There are no known operating potable or nonpotable water wells (other than monitoring wells)

located within 1 mile downgradient or crossgradient from the site. Surface drainage by overland flow from the site is collected in the Base storm sewer network and transported to the wastewater lagoon in the southeastern corner of the Base. Surface soil contamination at the site is limited, and is not expected to impact surface water quality.

The potential for exposure to contaminated water originating from the site through ingestion is low because Base access is restricted and Base drinking water does not come from wells located downgradient from PS-2. There are residential areas that rely on domestic wells for drinking water near the eastern boundary of the Base. The closest known residential housing downgradient from the site is across Rambo Road adjacent to the eastern Base boundary, approximately 6,000 feet from the site. Site contaminants are not expected to migrate to these drinking water wells at concentrations exceeding regulatory levels intended to be protective of human health and the environment. However, the potential impacts on these wells will be of primary importance for assessing the feasibility of intrinsic remediation at PS-2 and will be considered in greater detail once additional site data essential for the evaluation of intrinsic remediation have been collected.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the TS and to demonstrate that intrinsic remediation of fuel-related contaminants is occurring, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the TS.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the groundwater surface in site monitoring wells;
- Locations of potential groundwater preferential flow pathways and recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimate of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Groundwater temperature; and
- Determination of extent and thickness of mobile and residual LNAPL.

Chemical hydrogeologic characteristics to be determined include:

- Dissolved oxygen concentration;
- Specific conductance;
- pH;
- Chemical analysis of mobile LNAPL to determine mass fraction of BTEX; and
- Additional chemical analysis of groundwater and soil for the parameters listed in Table 3.1.

TABLE 3.1
ANALYTICAL PROTOCOL FOR PS-2
GROUNDWATER AND SOIL SAMPLES
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

MATRIX Analyte	**METHOD**	**FIELD (F) OR FIXED-BASE LABORATORY (L)**
WATER		
Total Iron	Colorimetric, HACH Method 8008	F
Ferrous Iron (Fe^{2+})	Colorimetric, HACH Method 8146	F
Ferric Iron (Fe^{3+})	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034	F
Sulfate	Colorimetric, HACH Method 8051	F
Nitrate	Titrimetric, HACH Method 8039	F
Nitrite	Titrimetric, HACH Method 8507	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	Direct reading meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1, direct reading meter	F
Carbon Dioxide	Titrimetric, HACH Method 1436-01	F
Alkalinity (Carbonate [CO_3^{2-}]	F = Titrimetric, HACH Method 8221	F
and Bicarbonate [HCO3-])	L = EPA method 310.1	L
Nitrate + Nitrite	EPA Method 353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane, Ethene	RSKSOP-147	L
Dissolved Organic Carbon	RSKSOP-102	L
Aromatic Hydrocarbons	RSKSOP-148	L
Fuel Carbon	RSKSOP-148	L
SOIL		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	RSKSOP-124, modified	L
Total Hydrocarbons	RSKSOP-174	L
FREE PRODUCT		
BTEX Mass Fraction	GC/MS, Direct Injection	L

In order to obtain these data, soil, groundwater, free product samples will be collected and analyzed. The following sections describe the procedures that will be followed when collecting additional site-specific data. Soil sampling and monitoring point installation will be accomplished using the Geoprobe® system as described in Sections 3.1 and 3.2. Soil core sample collection procedures are described in Section 3.1. Monitoring point installation procedures are described in Section 3.2. Groundwater sampling procedures for monitoring wells and newly installed groundwater monitoring points are described in Section 3.3. Measurement procedures for aquifer parameters (e.g., hydraulic conductivity) are described in Section 3.4.

3.1 SOIL SAMPLING

The following sections describe sampling locations, sample collection techniques, equipment decontamination procedures, site restoration, and management of investigation-derived waste materials.

3.1.1 Soil Sample Locations and Required Analyses

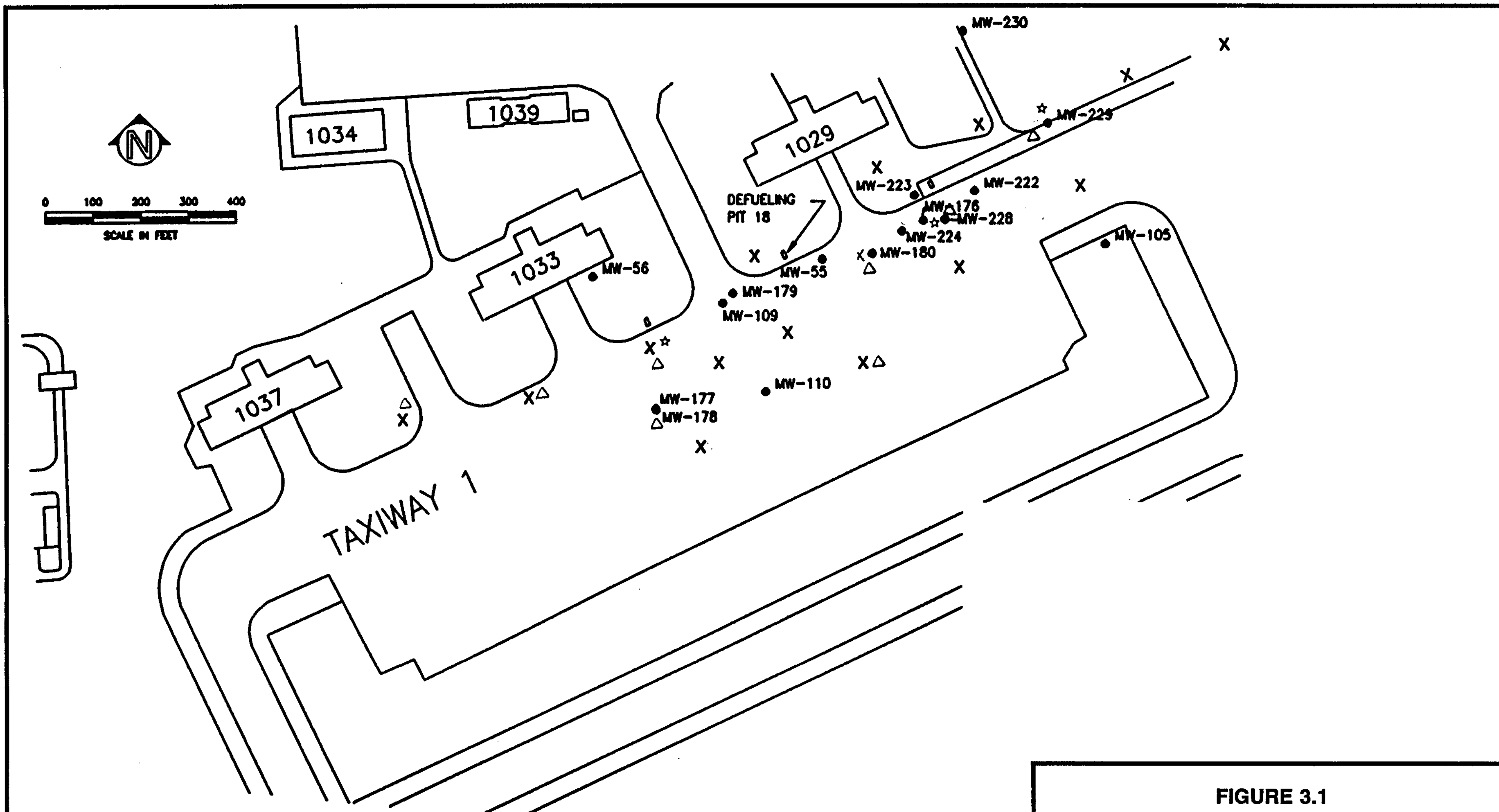
Soil samples will be collected at all Geoprobe® and monitoring point installation locations. Figure 3.1 identifies the proposed locations for soil sample collection at PS-2. Table 3.1 presents an analytical protocol for groundwater and soil samples, and Appendix A contains detailed information on the analyses and methods to be used during this sampling effort.

A minimum of two samples will be collected from each Geoprobe® hole location. One sample will be taken at the water table, and one will be taken at the depth of maximum BTEX contamination as determined by soil headspace screening. Sampling locations include suspected source areas in the vicinity of the monitoring well cluster MW-177/MW-178, monitoring well cluster MW-176/MW-228, and the bioventing system near defueling pit 19. Soil samples also will be collected from at least one location upgradient and downgradient from each of these suspected source areas. Additional samples will be collected at the discretion of the Parsons ES field scientist.

A portion of each sample will be used to measure soil headspace, and another portion of selected samples will be sent to the USEPA mobile laboratory for analytical analysis. Each laboratory soil sample will be placed in an analyte-appropriate sample container and hand-delivered to USEPA field personnel for analysis of total hydrocarbons, aromatic hydrocarbons, and moisture content using the procedures presented in Table 3.1. In addition, at least two samples will be analyzed for total organic carbon (TOC) from locations upgradient, crossgradient, or far downgradient from the contaminant source. Each headspace screening sample will be placed in a sealed plastic bag or mason jar and allowed to sit for at least 5 minutes. Volatile organic compounds (VOCs) in soil headspace will then be determined using an organic vapor meter (OVM), and the results will be recorded in the field records by the Parsons ES field scientist.

3.1.2 Sample Collection Using the Geoprobe® System

Soil samples will be collected using a Geoprobe® system, a hydraulically powered percussion/probing machine capable of advancing sampling tools through



LEGEND

MW-112	MONITORING WELL
X	PROPOSED SHALLOW MONITORING POINT
☆	PROPOSED DEEP MONITORING POINT
△	PROPOSED GEOPROBE® SOIL SAMPLING LOCATION

Sources: ICF Technology Inc., 1995.

FIGURE 3.1

PROPOSED SAMPLING AND MONITORING POINT LOCATIONS

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unconsolidated soils. This system allows the rapid collection of soil, soil gas, and groundwater samples at shallow depths while minimizing the generation of investigation-derived waste materials. Figure 3.2 is a diagram of the Geoprobe® system.

Soil samples will be collected using a probe-drive sampler. The probe-drive sampler serves as both the driving point and the sample collection device and is attached to the leading end of the probe rods. To collect a soil sample, the sampler is pushed or driven to the desired sampling depth, the drive point is retracted to open the sampling barrel, and the sampler is subsequently pushed into the undisturbed soils. The soil cores are retained within brass, stainless steel, or clear acetate liners inside the sampling barrel. The probe rods are then retracted, bringing the sampling device to the surface. The soil sample can then be extruded from the liners for lithologic logging, or the liners can be capped and undisturbed samples can be submitted to the analytical laboratory for testing.

If the probe-drive sampling techniques described above are inappropriate, inadequate, or unable to efficiently provide sufficient soil samples for the characterization of the site, continuous soil samples will be obtained from conventional soil boreholes using a hand auger or similar method judged acceptable by the Parsons ES field scientist. Procedures will be modified, if necessary, to ensure good sample recovery.

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic log form is presented in Figure 3.3. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Depths of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

Base personnel will be responsible for identifying the location of all utility lines, USTs, fuel lines, or any other underground infrastructure prior to any sampling activities. All necessary digging permits will be obtained by Base personnel prior to mobilizing to the field. Base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed locations. Because PS-2 is located on a part of the Base used by the National Guard, Base personnel will be

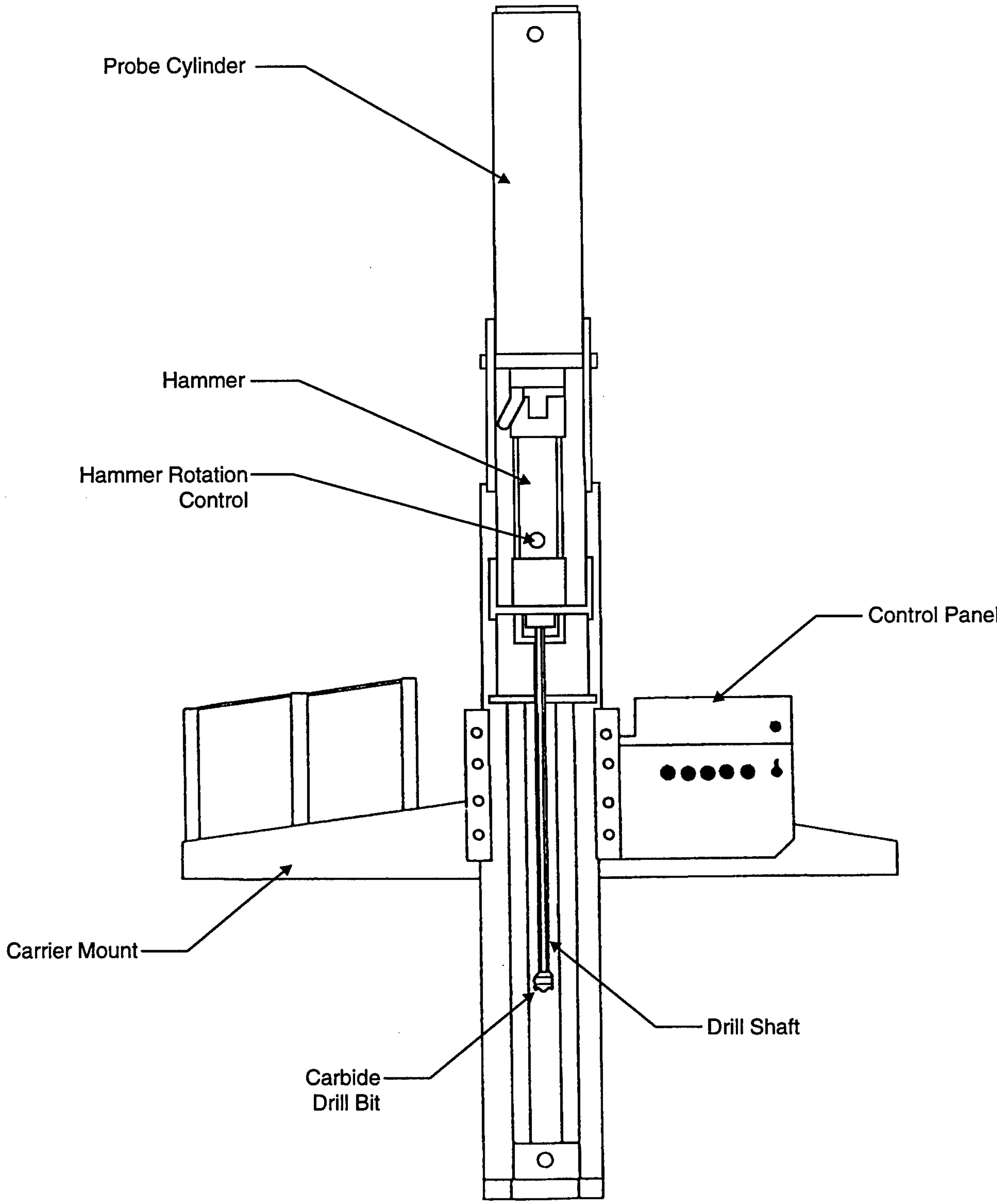

Figure 3.2

CROSS SECTION OF GEOPROBE®

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COREL/DRAW/GEOPROBE.CDR NAP 8/29/95 -TIF

GEOLOGIC BORING LOG

BORING NO.:		CONTRACTOR:		DATE SPUD:	
CLIENT:		RIG TYPE:		DATE CMPL.:	
JOB NO.:		DRLG METHOD:		ELEVATION:	
LOCATION:		BORING DIA.:		TEMP:	
GEOLOGIST:		DRLG FLUID:		WEATHER:	

COMENTS:

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1											
	5											
	10											
	15											
	20											
	25											
	30											
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

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responsible for alerting appropriate WANG personnel of upcoming investigations. Parsons ES will be responsible for providing trained operators for the Geoprobe®.

3.1.3 Datum Survey

The horizontal location of all soil sampling locations relative to established Base coordinates will be measured by a surveyor. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface also will be measured to the nearest 0.1 foot relative to USGS msl data.

3.1.4 Site Restoration

After sampling is complete, each sampling location will be restored as closely to its original condition as possible. Holes created by the Geoprobe® in sandy soils similar to those found at the Base tend to cave in soon after extraction of the drive sampler. However, any test holes remaining open after extraction of the probe-drive will be sealed with hydrated bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater. Concrete will be used to top off holes punched through asphalt or concrete. The concrete plug will be flush with and at least as thick as the surrounding asphalt or concrete Soil sampling using the Geoprobe® creates low volumes of soil waste. Soil not used for sampling will be placed in 55-gallon drums, labeled, and transported to a Base-designated holding location while disposal is being arranged.

3.1.5 Equipment Decontamination Procedures

Prior to arriving at the site, and between each sampling location, probe rods, tips, sleeves, pushrods, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash or Alconox® wash with a potable water rinse. Between each soil sample, the sampling barrel will be disassembled and decontaminated with Alconox® and potable water. The barrel then will be rinsed with deionized water and reassembled with new liners. Between uses, the sampling barrel will be wrapped in clean plastic or foil to prevent contamination. Only potable water will be used for decontamination.

All rinseate will be collected in 55-gallon drums. Filled 55-gallon drums will be labeled and transported to a Base-designated holding location while disposal is being arranged. The Base will be responsible for signing required waste shipping and disposal manifests.

Potable water to be used during equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

3.2 MONITORING POINT INSTALLATION

To further characterize site hydrogeologic conditions, up to 18 groundwater monitoring points may be installed at PS-2 to supplement the site monitoring wells. The following sections describe the proposed monitoring point locations and completion intervals, monitoring point installation, monitoring point development, and equipment decontamination procedures.

3.2.1 Monitoring Point Locations and Completion Intervals

The locations of 18 proposed groundwater monitoring points at PS-2 are identified on Figure 3.1. The proposed locations for the new monitoring points were determined from a review of data gathered during previous site activities. Monitoring point locations were selected to provide hydrogeologic data necessary for successful implementation of the Bioplume II model and to monitor potential fuel hydrocarbon migration from the site. Monitoring point locations were selected to define four aspects of the site: 1) the magnitude of the mobile LNAPL and dissolved BTEX concentrations within suspected source areas, 2) the extent of contamination, 3) the horizontal distribution of dissolved BTEX, and 4) the hydrogeology and groundwater flow direction at the site. The proposed locations shown on Figure 3.1 may be modified in the field as a result of encountered field conditions and acquired field data.

Three monitoring points will be installed in suspected source areas A shallow and deep monitoring point will be installed in the vicinity of VMP-1 near defueling pit 19. A single deep monitoring point will be installed in the area of mobile LNAPL associated with the monitoring wells MW-176, -228, -228A, and -228B. These points have the dual purpose of evaluating source area concentrations as well as the vertical extent of contamination within the source areas. Twelve shallow monitoring points are proposed to define the extent and configuration of the BTEX and mobile LNAPL plumes emanating from the suspected source areas. An additional two shallow monitoring points have been designated for areas upgradient from the dissolved BTEX plumes in order to evaluate background conditions at PS-2. A monitoring point screened near the bottom of the unconsolidated alluvium is proposed to be installed adjacent to monitoring well MW-229 in order to investigate the vertical extent of dissolved BTEX downgradient from the MW-176/228 source area. Because site conditions cannot always be predicted with complete accuracy prior to performance of the field work, two optional monitoring points have been reserved to further define the extent of contamination, the source areas, or the background site conditions.

Each shallow monitoring point will have a screened interval of approximately 3 feet placed near the top of the saturated zone. Deep monitoring points will be placed immediately above the bedrock basalt. The exact depth and location of monitoring points will be determined by the Parsons ES field scientist on the basis of site conditions. The proposed screened intervals of approximately 3 feet or less will help mitigate the dilution of water samples from potential vertical mixing of contaminated and uncontaminated groundwater in the monitoring point casing. Adjustments of the depth and length of the screened interval of the monitoring points may be necessary in response to actual aquifer conditions and contaminant distribution identified during Geoprobe® testing.

3.2.2 Monitoring Point Installation Procedures

3.2.2.1 Pre-Placement Activities

All necessary digging, coring, and drilling permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed Geoprobe® locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 3.1.1.

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

3.2.2.2 Monitoring Point Materials Decontamination

Monitoring point installation and completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, the well points and tubing will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used.

3.2.2.3 Installation and Materials

This section describes the procedures to be used for installation of monitoring points. Monitoring points will be installed using either 0.375-inch Teflon® tubing connected to a 0.5-inch-diameter stainless steel screen or a 0.5-inch inside-diameter (ID)/0.75-inch outside-diameter (OD) polyvinyl chloride (PVC) screen and casing.

If subsurface conditions permit, shallow monitoring points will be constructed of 0.75-inch OD-/0.5-inch-ID PVC casing and well screen to provide additional water level information. Approximately 3 feet of factory-slotted screen will be installed for each shallow monitoring point. Effective installation of the shallow monitoring points requires that the boreholes remain open upon completion of drilling. Shallow 0.5-inch-ID PVC monitoring points will be installed by punching and sampling a borehole with the Geoprobe®. Upon removing the rods, the borehole depth will be measured to determine if the hole remains open. If the borehole remains open, the 0.5-inch-ID PVC casing and screen will be placed at the appropriate depths. The annular space around the screen will be filled with sand filter pack, and the annulus around the casing will be filled with grout or bentonite. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4). This information will become part of the permanent field record for the site.

Monitoring point screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 0.5 inch. The screens will be factory slotted with 0.01-inch openings. Shallow monitoring point screens will be placed to sample and provide water level information at or near the water table. Blank monitoring point casing will be constructed of Schedule 40 PVC with an ID of 0.5 inch. All monitoring point casing sections will be flush-threaded; joints will not be glued. The casing at each monitoring point will be fitted with a bottom cap and a top cap constructed of PVC.

MONITORING POINT INSTALLATION RECORD

JOB NAME ________________ MONITORING POINT NUMBER ________

JOB NUMBER ________ INSTALLATION DATE ________ LOCATION ________

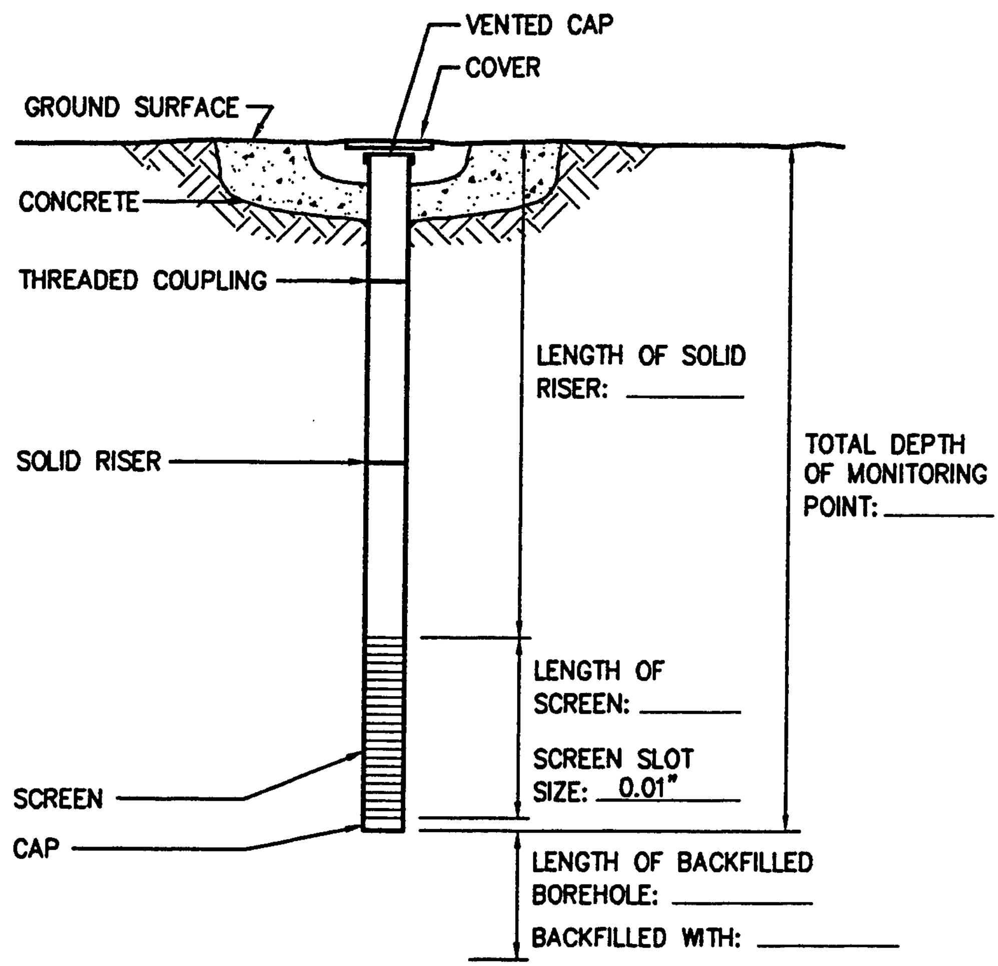
DATUM ELEVATION ________________ GROUND SURFACE ELEVATION ________

DATUM FOR WATER LEVEL MEASUREMENT ________________

SCREEN DIAMETER & MATERIAL ________________ SLOT SIZE ________

RISER DIAMETER & MATERIAL ________________ BOREHOLE DIAMETER ________

CONE PENETROMETER CONTRACTOR ________________ ES REPRESENTATIVE ________



(NOT TO SCALE)

STABILIZED WATER LEVEL ________ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH ______ FEET BELOW DATUM.

GROUND SURFACE ________ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

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If subsurface conditions do not permit the boreholes to remain open (i.e. the formation collapses in the hole), monitoring points will be constructed of a sacrificial drive point attached to a length of 0.5-inch-diameter stainless steel mesh that functions as the well screen, which in turn is connected to 0.375-inch Teflon® tubing. Holes are less likely to remain open for the installation of the deeper top-of-bedrock wells than the shallower top-of-water-table wells. To install tubing-cased monitoring points, the borehole is punched and sampled to several feet above the target depth for the monitoring point. The probe rods are withdrawn from the borehole, and the soil sampler is replaced with the well point assembly. An appropriate length of Teflon® tubing is threaded through the probe rods and attached to the well point. The assembly is lowered into the borehole and then driven down to the target depth and sampling zone. The probe rods are removed, leaving the sacrificial tip, screen assembly, and tubing behind. The soil is likely to cave in around the screen and tube assembly; where this does not occur, silica sand will be emplaced to create a sand pack around the well point, and the borehole annular space around the tubing above the sand pack will be filled with granular bentonite or grout to seal it. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4).

Should 0.5-inch-ID PVC shallow monitoring points not be installed, the only resulting data gap would be the lack of water level information for that particular location. The decision to install 0.5-inch-ID PVC monitoring points will be made in the field once the open-hole stability of subsurface soils and Geoprobe® equipment can be evaluated.

The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

3.2.2.4 Monitoring Point Completion

Monitoring points will be completed at grade with the protective cover cemented in place using concrete blended into the existing pavement. Additional specifications for completion of monitoring points along the flight-line will be provided by 92 CES/CEVR personnel. Where pavement is not present, the protective cover will be raised slightly above the ground surface, with a 2-foot-square concrete pad that will slope gently away from the cover to facilitate runoff during precipitation events. After monitoring point completion, each site will be restored as closely as possible to its original condition.

3.2.3 Monitoring Point Development and Records

The new monitoring points will be developed prior to sampling to remove fine sediments from the portion of the formation adjacent to the screen. Development will be accomplished by lowering high density polyethylene (HDPE) tubing into the well or attaching Teflon® tubing to the pump lines and removing water with a peristaltic pump until pH, temperature, specific conductivity, and water clarity (turbidity) stabilize. At a minimum, 10 casing volumes of water will be developed from the monitoring point. In the event that 10 casing volumes of water cannot be recovered as a result of low water production, the water volume recovered and the deficiency will be noted in the

development records. Monitoring point development will occur a minimum of 24 hours prior to sampling.

A development record will be maintained for each new monitoring point. The development record will be completed in the field by the field scientist. Figure 3.5 is an example of a development record used for similar well installations. Development records will include:

- Monitoring point number;
- Date and time of development;
- Development method;
- Monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and monitoring point depth (0.5-inch ID PVC monitoring points only); and
- Field analytical measurements, including pH and specific conductivity.

Development waters will be collected in 55-gallon drums. Filled 55-gallon drums will be labeled and transported to a Base-designated holding location while disposal is being arranged. The Base will be responsible for signing required shipping and disposal manifests.

3.2.4 Monitoring Point Location and Datum Survey

The location and elevation of the monitoring points will be surveyed by a registered surveyor soon after completion. Horizontal coordinates will be measured to the nearest 0.1 foot relative to established Base coordinates. The elevation of the flush-mount casing and measurement datum (top of interior casing) will be measured to the nearest 0.01 foot relative to USGS msl data.

3.2.5 Water Level Measurements

Water levels at all site monitoring points and wells will be measured within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe or if mobile LNAPL is present an oil-water interface probe.

3.3 GROUNDWATER SAMPLING PROCEDURES

This section describes the scope of work required for collection of groundwater quality samples. Samples will be collected from previously installed monitoring wells and newly installed monitoring points. A peristaltic pump with dedicated HDPE tubing will be used to collect groundwater samples at monitoring points and wells. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

MONITORING POINT DEVELOPMENT RECORD

Page__ of__

Job Number: 722450.18
Location: ____________________
Well Number____________________

Job Name: Fairchild AFB, Washington
By____________________ Date________
Measurement Datum____________________

Pre-Development Information

Time (Start):

Water Level:

Total Depth of Well:

Water Characteristics

Color____________________ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material____________________
pH__________ Temperature(oF oC) __________
Specific Conductance(µS/cm)____________________

Interim Water Characteristics

Gallons Removed

pH

Temperature (oF oC)

Specific Conductance(µS/cm)

Post-Development Information

Time (Finish):

Water Level:

Total Depth of Well:

Approximate Volume Removed:

Water Characteristics

Color____________________ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material____________________
pH__________ Temperature(oF oC) __________
Specific Conductance(µS/cm)____________________

Comments:

FIGURE 3.5

MONITORING POINT DEVELOPMENT RECORD

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Sampling will be conducted by qualified scientists and technicians from Parson ES and the USEPA RSKERL who are trained in the conduct of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference. Groundwater sampling includes the following activities:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well/point integrity including:
  - Protective cover, cap, and lock,
  - External surface seal and pad,
  - Monitoring well/point stick-up, cap, and datum reference, and
  - Internal surface seal;
- Groundwater sampling, including:
  - Water level and product thickness measurements,
  - Visual inspection of sample water,
  - Monitoring well/point casing evacuation, and
  - Sample collection;
- Sample preservation and shipment, including:
  - Sample preparation,
  - Onsite measurement of physical parameters, and
  - Sample labeling;
- Completion of sampling records: and
- Sample disposition.

Detailed groundwater sampling and sample handling procedures are presented in following sections.

3.3.1 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.3.1.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the split-spoon soil samplers, sampling pumps, water level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Given the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling record (Figure 3.6).

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the USEPA mobile laboratory's permanent record of the sampling event.

3.3.1.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of dissolved oxygen (DO), pH, electrical conductivity, temperature, redox potential, sulfate, nitrate, ferrous iron (Fe^{2+}), and other field parameters listed on Table 3.1.

3.3.2 Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The primary ways in which sample contamination can occur is through contact with improperly cleaned sampling equipment. To prevent such contamination, the water level probe and cable used to determine static water levels and total well/point depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.1.1. Dedicated tubing will be used at each well/point developed, purged, and/or sampled with the peristaltic pump. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile or latex gloves will be worn each time a different monitoring point or well is sampled. The following paragraphs present the procedures to be followed for groundwater sample collection from groundwater monitoring points and wells. These activities will be performed in the order presented below. Exceptions to this procedure will be noted in the field scientist's field notebook or on the groundwater sampling record.

3.3.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the monitoring points/wells will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring point/well.

GROUNDWATER SAMPLING RECORD

SAMPLING LOCATION ____________________
SAMPLING DATE(S)____________________
MONITORING WELL ____________________
(number)

REASON FOR SAMPLING: [ ] Regular Sampling; [ ] Special Sampling;
DATE AND TIME OF SAMPLING: ____________, 19___ ________ a.m./p.m.
SAMPLE COLLECTED BY: ____________________ of ____________________
WEATHER:____________________
DATUM FOR WATER DEPTH MEASUREMENT (Describe):____________________

MONITORING WELL CONDITION:
[ ] LOCKED: [ ] UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS:____________________
INNER PVC CASING CONDITION IS:____________________
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
[ ] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
[ ] MONITORING WELL REQUIRED REPAIR (describe):____________________

Check-off
1 [ ] EQUIPMENT CLEANED BEFORE USE WITH____________________
Items Cleaned (List):____________________

2 [ ] PRODUCT DEPTH ____________________FT. BELOW DATUM
Measured with:____________________

WATER DEPTH ____________________FT. BELOW DATUM
Measured with:____________________

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance:____________________
Odor:____________________
Other Comments:____________________

4 [ ] WELL EVACUATION:
Method:____________________
Volume Removed:____________________
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors:____________________
Other comments:____________________

FIGURE 3.6

GROUNDWATER SAMPLING RECORD

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

GROUND WATER SAMPLING RECORD (Continued)

MONITORING WELL ______________

5 [ ] SAMPLE EXTRACTION METHOD:

[ ] Bailer made of: ______________________________
[ ] Pump, type: _
[ ] Other, describe: ______________________________
____

Sample obtained is [ ] GRAB; [ ] COMPOSITE SAMPLE

6 [ ] ON-SITE MEASUREMENTS:

Temp: ________ ° _____	Measured with: ______________
pH: ______________	Measured with: ______________
Conductivity: __________	Measured with: ______________
Dissolved Oxygen: __________	Measured with: ______________
Redox Potential: __________	Measured with: ______________
Salinity: __________	Measured with: ______________
Nitrate: __________	Measured with: ______________
Sulfate: __________	Measured with: ______________
Ferrous Iron: __________	Measured with: ______________

Other: ______________________________
____

7 [ ] SAMPLE CONTAINERS (material, number, size): ______________________________
____
____
____

8 [ ] ON-SITE SAMPLE TREATMENT:

[ ] Filtration:

Method______________	Containers: ______________
Method______________	Containers: ______________
Method______________	Containers: ______________

[ ] Preservatives added:

Method______________	Containers: ______________
Method______________	Containers: ______________
Method______________	Containers: ______________
Method______________	Containers: ______________

9 [ ] CONTAINER HANDLING:

[ ] Container Sides Labeled
[ ] Container Lids Taped
[ ] Containers Placed in Ice Chest

10 [ ] OTHER COMMENTS: ______________________________
____
____
____
____

FIGURE 3.6 (Continued)

GROUNDWATER SAMPLING RECORD

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

3.3.2.2 Water Level and Total Depth Measurements

Prior to removing water from the monitoring point/well, the static water level will be measured. An electric water level probe or oil/water interface probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring point/well and the depth will be measured to the nearest 0.01 foot. If free-phase product (mobile LNAPL) is present, the total depth of the well from installation records will be used to avoid excessive contamination of the water level probe and cord. Based on these measurements, the volume of water to be purged from the monitoring point/well will be calculated. If mobile LNAPL is encountered, the thickness of the product will be measured with an oil/water interface probe.

3.3.2.3 Monitoring Point/Well Purging

The volume of water contained within the monitoring point/well casing at the time of sampling will be calculated, and at least three times the calculated volume will be removed from the well. A peristaltic pump will be used for monitoring point/well purging. All purge waters will be collected in 55-gallon drums. Filled 55-gallon drums will be labeled and transported to a Base-designated holding location while disposal is being arranged. The Base will be responsible for signing required shipping and disposal manifests.

If a monitoring point or well is evacuated to a dry state during purging, the point/well will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring point/well to obtain the necessary sample quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

3.3.2.4 Sample Extraction

Dedicated HDPE tubing and a peristaltic pump will be used to extract groundwater samples from monitoring points and wells. The tubing will be lowered through the casing into the water gently to prevent splashing. This step is omitted if the monitoring point is constructed of Teflon® tubing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the USEPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be disposed of in the same manner as purge water.

3.3.3 Onsite Groundwater Parameter Measurement

As indicated on Table 3.1, many of the groundwater chemical parameters will be measured onsite by USEPA staff. Some of the measurements will be made with direct-reading meters, while others will be made using a HACH® portable colorimeter in

accordance with specific HACH® analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of laboratory-grade, phosphate-free detergent (e.g., Alconox®) and water, and rinsing with isopropyl alcohol and deionized water to prevent interference or cross-contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric or colorimetric methods, the analysis will be repeated by diluting the groundwater sample with distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps and properly disposed.

3.3.3.1 Dissolved Oxygen Measurements

DO measurements will be made using a meter with a downhole oxygen sensor or a sensor in a flow-through cell before and immediately following groundwater sample acquisition. When DO measurements are taken in monitoring points/wells that have not yet been sampled, the monitoring points/wells will be purged until DO levels stabilize.

3.3.3.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a flow-through cell or a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded in the groundwater sampling record (Figure 3.6).

3.3.3.3 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced USEPA RSKERL scientists via titrimetric analysis using USEPA-approved HACH® Method 8221 (0 to 5,000 mg/L as calcium carbonate) or a similar method. Alkalinity of the groundwater sample also will be measured at the fixed-based laboratory using USEPA method 310.1.

3.3.3.4 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced USEPA RSKERL scientists via colorimetric analysis using a HACH® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with HACH® Method 8039 (0 to 30.0 mg/L NO_3). Nitrite concentrations in groundwater samples will be analyzed after preparation with EPA-approved HACH® Method 8507 (0 to 0.35 mg/L NO_2) or a similar method.

3.3.3.5 Carbon Dioxide Measurements

Carbon dioxide concentrations in groundwater will be measured in the field by USEPA RSKERL scientists via titrimetric analysis using HACH® Method 1436-01 (0 to 250 mg/L as CO_2). Sample preparation and disposal procedures are the same as outlined at the beginning of Section 3.3.3.

3.3.3.6 Sulfate Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments. A USEPA RSKERL scientist will measure sulfate concentrations via colorimetric analysis with a HACH® DR/700 Portable Colorimeter. After appropriate sample preparation. EPA-approved HACH® Method 8051 (0 to 70.0 mg/L SO_4) or similar will be used to prepare samples and analyze sulfate concentrations.

3.3.3.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the redox potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. HACH® Method 8008 (or similar) for total soluble iron (0 to 3.0 mg/L Fe^{3+} + Fe^{2+}) and HACH® Method 8146 (or similar) for ferrous iron (0 to 3.0 mg/L Fe^{2+}) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.3.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a HACH® DR/700 Portable Colorimeter. USEPA-approved HACH® Method 8034 (0 to 20.0 mg/L) or similar will be used for quantitation of manganese concentrations. Sample preparation and disposal procedures are outlined earlier in Section 3.3.3.

3.3.3.9 Reduction/Oxidation Potential

The reduction/oxidation (redox) potential of groundwater is an indication of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. Redox potential can be used to provide real-time data on the location of the contaminant

plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a groundwater sample taken inside the contaminant plume should be somewhat less than that taken in an upgradient location.

The redox potential of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis or in a flow through cell.

3.4 SAMPLE HANDLING FOR LABORATORY ANALYSIS

This section describes the handling of samples from the time of sampling until the samples are delivered to USEPA field laboratory.

3.4.1 Sample Preservation

The USEPA mobile laboratory support personnel will add any necessary chemical preservatives prior to filling the sample containers. Samples will be prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of as close to 4 degrees centigrade (°C) as possible. Samples will be delivered promptly to USEPA field laboratory personnel, who will be responsible for shipment of appropriate samples to the RSKERL in Ada, Oklahoma for analysis.

3.4.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the USEPA field laboratory (see Appendix A). The sample containers will be filled as described in Section 3.3.2.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., groundwater, soil);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the onsite USEPA field laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by hand to the USEPA field laboratory. Delivery will occur as soon as possible after sample acquisition.

3.4.4 Chain-of-Custody Control

Chain-of-custody documentation for the shipment of samples from the USEPA field laboratory to the RSKERL analytical laboratory in Ada, Oklahoma, will be the responsibility of the USEPA field personnel.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance, and
  - Sample odor;
- Weather conditions;
- Water level prior to purging (groundwater samples only);
- Total monitoring well/point depth (groundwater samples only);
- Sample depth (soil samples only);
- Purge volume (groundwater samples only);
- Water level after purging (groundwater samples only);
- Monitoring well/point condition (groundwater samples only);
- Sampler's identification;

- Field measurements of pH, temperature, DO, and specific conductivity (groundwater samples only); and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.6 shows an example of the groundwater sampling record. Soil sampling information will be recorded in the field log book.

3.4.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater and soil samples as well as the QA/QC samples described in Section 5. The analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, USEPA RSKERL personnel will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with USEPA protocol or those reported in Appendix A of this plan.

USEPA laboratory support personnel will specify the necessary QC samples and prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory. Containers, ice chests with adequate padding, and cooling media will be provided by USEPA RSKERL laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the field laboratory.

3.5 AQUIFER TESTING

Slug tests will be conducted on selected monitoring wells to estimate the hydraulic conductivity of unconsolidated deposits at the site. This information is required to accurately estimate the velocity of groundwater and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 ft^2/day. Slug testing can be performed using either a rising head or a falling head test; at this site, both methods will be used in sequence.

3.5.1 Definitions

- **Hydraulic Conductivity (K)**. A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T)**. A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test**. Two types of testing are possible: rising head and falling head tests. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.

- **Rising Head Test**. A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.
- **Falling Head Test**. A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.5.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon®, PVC, or metal slugs;
- Nylon or polypropylene rope;
- Electric water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger®, In-Situ, Inc. Model SE1000B, or equivalent).

3.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Slug testing will proceed only after multiple water level measurements over time show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; in addition, slug tests will not be performed on wells with free product. The field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.3.1.1.

3.5.4 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following steps describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.

2. Open the well. Where wells are equipped with watertight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.

3. Prepare the aquifer slug test data form (Figure 3.7) with entries for:

   - Borehole/well number,
   - Project number,
   - Project name,
   - Aquifer testing team,
   - Climatic data,
   - Ground surface elevation,
   - Top of well casing elevation,
   - Identification of measuring equipment being used,
   - Page number,
   - Static water level, and
   - Date.

4. Measure the static water level in the well to the nearest 0.01 foot.

5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.

6. Lower the decontaminated slug into the well to just above the water level in the well.

7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.

8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

AQUIFER SLUG TEST DATA SHEET

Location: ______________________ Client: AFCEE Well No.____________
Job No.: 722450.18 Field Scientist____________ Date____________
Water Level______________________ Total Well Depth______________________
Measuring Datum______________________ Elevation of Datum______________________
Weather______________________ Temp______________________
Comments____

Beginning Time	Ending Time	Initial Head Reading	Ending Head Reading	Test Type (Rise/Fall)	File Name	Comments

FIGURE 3.7

AQUIFER TEST
DATA FORM

Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS
ENGINEERING SCIENCE, INC.
Denver, Colorado

3.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.

2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.

3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV™ and the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined aquifer conditions.

SECTION 4

REMEDIAL OPTION EVALUATION AND TS REPORT

Upon completion of field work, the Bioplume II numerical groundwater model will be used to determine the fate and transport of BTEX dissolved in groundwater at the site. On the basis of model predictions of contaminant concentration and distribution through time, and of potential receptors and exposure pathways, the potential for receptor to be exposed to BTEX concentrations above those intended to be protective of human health and the environment will be assessed. If it is shown that intrinsic remediation of BTEX compounds at the sites is sufficient to reduce the potential risk to human health and the environment to acceptable levels, Parsons ES will recommend implementation of the intrinsic remediation option. If intrinsic remediation is chosen, Parsons ES will prepare a site-specific, long-term monitoring plan that will specify the locations of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation remedial option is deemed inappropriate for use at these sites, institutional controls such as groundwater or land use restrictions will be evaluated to determine if they will be sufficient to reduce the threat to human health and the environment to acceptable levels. If institutional controls are inappropriate, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial options will be recommended. Potential remedial options include, but are not limited to, bioslurping, groundwater pump-and-treat, enhanced biological treatment, bioventing, air sparging, and *in situ* reactive barrier walls. The reduction in dissolved BTEX that should result from remedial activities will be used to produce new input files for the groundwater models. The models will then be used to predict the BTEX source and plume (and risk) reduction that should result from remedial actions.

Upon completion of Bioplume II modeling and remedial option selection, a TS report detailing the results of the modeling and remedial option selection will be prepared. This report will follow the outline presented in Table 4.1 and will contain an introduction, site descriptions, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial approach for each site. This report will also contain the results of the site characterization activities described herein and a description of the models developed for each site.

TABLE 4.1
EXAMPLE TS REPORT OUTLINE
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

INTRODUCTION
- Scope and Objectives
- Site Background

SITE CHARACTERIZATION ACTIVITIES
- Sampling and Aquifer Testing Procedures

PHYSICAL CHARACTERISTICS OF THE STUDY AREA
- Surface Features
- Regional Geology and Hydrogeology
- Site Geology and Hydrogeology
- Climatological Characteristics

NATURE AND EXTENT OF CONTAMINATION
- Source Characterization
- Soil Chemistry
  - Residual Contamination
  - Total Organic Carbon
- Groundwater Chemistry
  - LNAPL Contamination
  - Dissolved Contamination
  - Groundwater Geochemistry
  - Expressed Assimilative Capacity

GROUNDWATER MODEL
- Model Description
- Conceptual Model Design and Assumptions
- Initial Model Setup
- Model Calibration
- Sensitivity Analysis
- Model Results
- Conclusions

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES
- Remedial Alternative Evaluation Criteria
  - Long-Term Effectiveness
  - Implementability (Technical, Administrative)
  - Cost (Capital, Operating, Present Worth)
- Factors Influencing Alternatives Development
  - Program Objectives
  - Contaminant Properties
  - Site-Specific Conditions
- Brief Description of Remedial Alternatives
  - Intrinsic Remediation with Long-Term Monitoring

TABLE 4.1
EXAMPLE TS REPORT OUTLINE
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Other Alternatives
Evaluation of Alternatives
Recommended Remedial Approach

LONG-TERM MONITORING PLAN
Overview
Monitoring Networks
Groundwater Sampling

CONCLUSIONS AND RECOMMENDATIONS

APPENDICES: Supporting Data and Documentation
Site-Specific Bioplume II Model Input and Results

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the mobile analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of as close to 4°C as possible.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate groundwater and soil samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

Soil and groundwater samples collected with the Geoprobe® sampling tips should provide sufficient volume for some duplicate analyses. Refer to Appendix A for further details on sample volume requirements.

One rinseate sample will be collected for every 10 or fewer groundwater samples collected from existing wells. Because disposable bailers may be used for this sampling event, the rinseate sample will consist of a sample of distilled water poured into a new disposable bailer or run through a new set of pump tubing and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs only.

A field blank will be collected for every 20 or fewer groundwater samples to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

TABLE 5.1
QA/QC SAMPLING PROGRAM
INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates	3 Groundwater and 2 Soil Samples (10%)	VOCs, TPH
Rinseate Blanks	2 Samples (5% of Groundwater Samples)	VOCs
Field Blanks	2 Samples (5% of Groundwater Samples)	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

m:\45024\workplan\t5-1.xls

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory. A trip blank will be transported inside each cooler which contains samples for VOC analysis. Trip blanks will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

SECTION 6

REFERENCES

Battelle Laboratories, 1985, *National Perspective on Sediment Quality*. Prepared for USEPA, Criteria and Standards Division, EPA Contract No 68-01-6986.

Battelle Denver Operations, 1989, *Installation Restoration Program, IRP Phase II, Stage I Confirmation/Quantification, Fairchild AFB, Washington*. Prepared for the USAF, Occupational and Environmental Health Laboratory, Brooks AFB, Texas.

Borden, R.C., and Bedient, P.B. 1986. Transport of dissolved hydrocarbons influenced by oxygen limited biodegradation - theoretical development. *Water Resources Research,* vol. 22, no. 13. p. 1973-82.

Bouwer, H., 1989, The Bouwer and Rice slug test - an update: *Ground Water*, 27(3), p. 304-309.

Bouwer, H., and Rice, R.C., 1976, A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells: *Water Resources Research*, 12(3), p. 423-428.

Bruce, L., Miller, T., and Hockman, B., 1991, Solubility versus equilibrium saturation of gasoline compounds - a method to estimate fuel/water partition coefficient using solubility or K_{OC}... In, A. Stanley (editor), *NWWAI/API Conference on Petroleum Hydrocarbons in Ground Water*: NWT/API, p. 571-582.

Cline, D.R., 1969, *Groundwater Resources and Related Geology North-central Spokane and Southeastern Stevens Counties of Washington*. State of Washington Department of Water Resource Water Supply Bulletin, No. 27.

Cline, P.V., Delfino, J.J., and Rao, P.S.C., 1991, Partitioning of aromatic constituents into water from gasoline and other complex solvent mixtures: *Environmental Science and Technology*: v. 17, no. 4, p. 227-231.

EA Engineering, Science, and Technology and Montgomery Watson Americas, Inc. (ES&T and MWA), 1995, *Analytical Data Informal Technical Information Report: Long Term Monitoring -- April 1995 Sampling Craig Road Landfill and Priority 1 Sites SW-1, PS-2, PS-8, WW-1, FT-01, Fairchild AFB, Washington.* May.

Engineering-Science, Inc., (ES) 1993, *Health and Safety Plan for the Bioplume Modeling Initiative*. Prepared for the Air Force Center for Environmental Excellence, Environmental Restoration Division, USAF Contract F41624-92-D-8036.

ES, 1994, *Part I: Bioventing Pilot Test Work Plan for PS-2, PS-1A, PS-1B, Building 2034, Building 2035 and Part II: Draft Bioventing Pilot Test Interim Results Report for PS-2, PS-1A, PS-1B, Building 2034, Building 2035*. June.

Flint, R. I., 1936, *Stratified Drift and Deglaciation of Eastern Washington*. USGS Bulletin Vol. 47.

Halliburton NUS (HNUS), 1993, *Installation Restoration Program (IRP) Remedial Investigation Report Priority One Operable Units: LF-01 (SW-1); SD-05 (IS-1); SS-18 (PS-2); SS-28 (PS-6); SS-27 (PS-8); WP-03 (WW-1); FT-04 (FT-1), Fairchild AFB, Washington*. February.

HNUS, 1994a, Work Plan: Floating Free Product Passive Recovery Treatability Study, On-Base Priority One Operable Unit Flightline, Fairchild AFB, March.

HNUS, 1994b, Treatability Study Letter Report 07: Floating Free Product Passive Recovery Treatability Study, On-Base Priority One Operable Unit Flightline Operable Unit, Site PS-2, Fairchild AFB. December.

HNUS, 1995a, Treatability Study Letter Report 08: Floating Free Product Passive Recovery Treatability Study, On-Base Priority One Operable Unit Flightline Operable Unit, Site PS-2, Fairchild AFB. January.

HNUS, 1995b, Treatability Study Letter Report 09: Floating Free Product Passive Recovery Treatability Study, On-Base Priority One Operable Unit Flightline Operable Unit, Site PS-2, Fairchild AFB. January.

Hvorslev, M. J., 1951, *Time Lag and Soil Permeability in Ground-Water Observations:* United States Corps of Engineers Waterways Experiment Station Bulletin 36, Vicksburg, Mississippi. 50p.

ICF Technology, Inc. (ICF), 1995, *Long Term Monitoring Report for Priority 1 Sites SW-1 (LF-01), PS-2 (SS-18), and PS-8 (SS-26) at Fairchild AFB, Washington*. June.

JRB Associates, 1985, *Installation Restoration Program IRP Phase I Records Search, 92nd Bombardment Wing (Heavy) Fairchild AFB, Washington*. Prepared for the USAF, Occupational and Environmental Health Laboratory, Brooks AFB, Texas.

Konikow, L. F., and Bredehoeft, J. D., 1978, Computer model of two-dimensional solute transport and dispersion in ground water: United States Geological Survey, Techniques of Water Resources Investigations of the United States Geological Survey, Book 7, Chapter C2.

Lee, M.D. 1988. Biorestoration of aquifers contaminated with organic compounds. *CRC Critical Reviews in Environmental Control*, v. 18. p. 29-89.

Rifai, H.S., Bedient, P.B., Wilson, J.T., Miller, K.M., and Armstrong, J.M. 1988. Biodegradation modeling at aviation fuel spill site," *Journal of Environmental Engineering*, v. 114, no. 5, p. 1007-1029.

Science Applications International Corporation (SAIC), 1990, *Site Characterization Summary Priority One Sites*. December.

Theis, C. V., 1935, *The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage*. Trans. Amer. Geophys. Union, Vol. 16.

US Geological Survey (USGS), 1973a, 7.5 Minute Quadrangle Map of the Four Lakes Quadrangle, Washington.

USGS, 1973b, 7.5 Minute Quadrangle Map of the Medical Lake Quadrangle, Washington.

USGS, 1986a, 7.5 Minute Quadrangle Map of the Airway Heights Quadrangle, Washington.

USGS, 1986b, 7.5 Minute Quadrangle Map of the Deep Creek Quadrangle, Washington.

van Genuchten, M. T., and Alves, W. J., 1982, *Analytical Solutions of the One-Dimensional Convective-Dispersive Solute Transport Equation:* US Department of Agriculture, Technical Bulletin Number 1661, 151p.

Wexler, 1992, Analytical solutions for one-, two-, and three-dimensional solute transport in ground-water systems with uniform flow: *United States Geological Survey, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3,* Chapter B7, 190p.

Wiedemeier, Todd H., Downey, Douglas C., Wilson, John T., Kampbell, Donald H., Miller, Ross N., and Hansen, Jerry E., 1995, *Draft Technical Protocol for Implementing the Intrinsic Remediation (Natural Attenuation) with Long-term Monitoring Option for Dissolved-phase Fuel Contamination in Ground Water.* Prepared by the Air Force Center for Environmental Excellence.

APPENDIX A

CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING REQUIREMENTS FOR GROUNDWATER SAMPLES

APPENDIX A

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Volatile organics	Gas chromatography/ mass spectrometry method SW8240.	Handbook method	Data is used to determine the extent of chlorinated solvent and aromatic hydrocarbon contamination, contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon®-lined cap; cool to 4°C	Fixed-base
Soil	Dehydrogenase enzyme activity (optional)	Colorimetric RSKSOP-100	Reduction of added triphenyltetrazolium chloride by soil microbes is measured colorimetrically; analyze immediately	An indicator of the presence of soil microbes, which are necessary for bioremediation to occur	At the beginning of the project	Collect 100 g of soil in a glass container	Field
Soil	Aromatic hydrocarbons (benzene, toluene, ethyl-benzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil; the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base
Soil gas	Carbon dioxide content of soil gas	Nondispersive infrared instrument operating over the range of approximately 0.1–15 percent	Soil gas carbon dioxide may be produced by the degradation of petroleum hydrocarbons	Data used to understand the carbon dioxide concentration gradient with depth and to infer the biological degradation of petroleum contaminants	Each sampling round	N/A	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil gas	Oxygen content of soil gas	Electrochemical oxygen meter operating over the range of 0–25 percent of oxygen in the soil gas sample	The concentration of soil gas oxygen is often related to the amount of biological activity, such as the degradation of petroleum hydrocarbons; soil gas oxygen concentrations may decrease to the point where anaerobic pathways dominate	Data are used to understand the oxygen concentration gradient with depth and to determine the presence or absence of aerobic degradation processes	Each sampling round	N/A	Field
Soil gas	Methane content of soil gas	Total combustible hydrocarbon meter using a platinum catalyst with a carbon trap, and operating in the low parts per million volume (ppmv) range	Methane is a product of the anaerobic degradation of petroleum hydrocarbons	Soil gas methane can be used to locate contaminated soil and to determine the presence of anaerobic processes; see discussion of data use for methane in water	Each sampling round	N/A	Field
Soil gas	Fuel hydrocarbon vapor content of soil gas	Total combustible hydrocarbon meter operating over a wide ppmv range	Soil gas hydrocarbons indicate the presence of these contaminants in the soil column	Data used to understand the petroleum hydrocarbon concentration gradient with depth and to locate the most heavily contaminated soils	Each sampling round	N/A	Field
Water	Ferrous (Fe^{+2})	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 ml of water in a glass container; acidify with hydrochloric acid per method	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ferrous (Fe^{+2})	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above	Each sampling round	Collect 100 ml of water in a glass container	Field
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100mL of water in a glass container	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl^- C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen *in situ*	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 100mL of water in glass container	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	A2320, titrimetric; E310.2, colorimetric	Handbook method	Same as above	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	Nitrate (NO_3^{-1})	HACH method # 8039 for high range method # 8192 for low range	Colorimetric	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO_4^{-2})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH method # 8051	Colorimetric	Same as above	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Dissolved sulfide (S^{-2})	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ethane, ethene	RSKSOP-114 (cont'd)	Ethane and ethene are analyzed in addition to the other analytes only if chlorinated hydrocarbons are contaminants suspected of undergoing biological transformation	Ethane and ethene are products of the bio-transformation of chlorinated hydrocarbons under anaerobic conditions. The presence of these chemicals may indicate that anaerobic degradation is occurring			
Water	Carbon dioxide	HACH test kit model CA-23 or CHEMetrics Method 4500	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect 100 mL of water in a glass container	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling	One time per year or as required by regulations	Volatile hydrocarbons–collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons–collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base
Water	Volatile Organics	GS/MS method SW8240	Handbook method	Method of analysis for chlorinated solvents and aromatic hydrocarbons for evaluation of cometabolic degradation; measured for regulatory compliance when chlorinated solvents are known site contaminants	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Dissolved organic carbon (DOC) (optional)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	An indirect index of microbial activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Temperature	E170.1	Field only	Well development	Each sampling round	N/A	Field
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to *Robert S. Kerr (Environmental Protection Agency Laboratory) Standard Operating Procedure.*
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.

APPENDIX B

ADDITIONAL SITE DATA

APPENDIX B - 1a

BOREHOLE LOGS
&
WELL COMPLETION DETAILS

Borehole PS2-MW

Log of Borehole

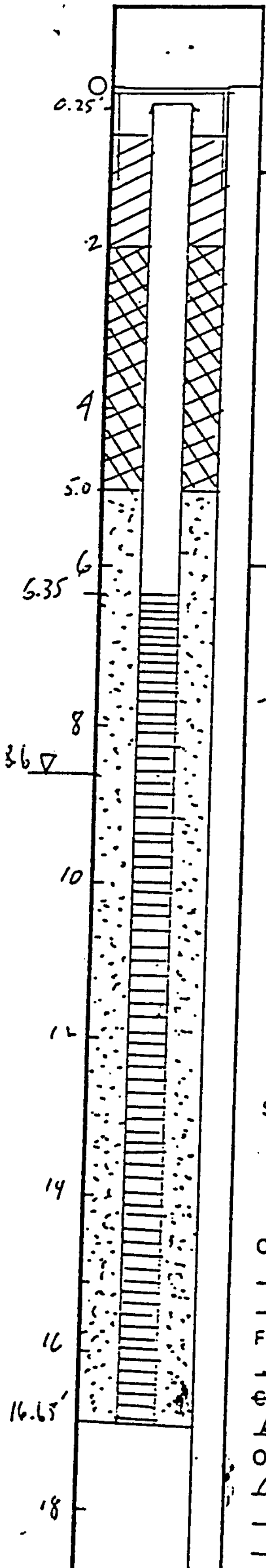
page 1 of 1

Project FAFB	Total Depth 16.65'	START / FINISH
Location PS2 - MW55	Borehole Dia 8"	Date 10/30/88 / 10/30/88
Geologic Log by James Moore	Depth to Fluid 8.6' BGS	Time 0802 / 0956
Driller Lynn Bartholomew	Rig Canterra 150	How Left Below
Geophysics by none	Bit(s) finger bit	ground well
Weather clear & mild	Fluid —	completion

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU hole	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0							0-3' - Asphalt - fill material overlying	
							3.0-3.5' - Organic rich silt	
3'	18,17,B		5		3-4.5		very fine grained, well sorted	
							5Y 2.5/1 black sl. moist (OL)	
							3.5-4.5 Silty sand, fine	
							gr. sand, well sorted sub	
							angular, qtz sand, med	
							dense, not plastic, sl. moist	
							5Y 4/1 dk gray (SM)	95%
8	7,7,7		2.5		8-9.5		8-9.5' - Silty Sand - predominantly	
							silt - well sorted w/ minor	
							fine gr. sand. and mica, very	
							loose - increasing moisture	
							content - organic rich	
							5Y 2.5/1 black (SM)	100%
13	6,10,34/5"		2.0		13-14.5		13-13.75 clay, very plastic	
							moist, soft, 5G 4/2 greyish green (CL)	
							13.75-14.25 - Sand w/ minor	
							silt well sorted, med-coarse gr.	
							subangular, predominately qtz	
							basalt & mica. very dense	
							saturated 5GY 4/1 dk grayish	
							green (SP)	80%
16.6			2.0		16		16.6' Bit refusal basalt?	0%
							Very hard	

Source: SAIC, 1990

HNU background 0.20 ppm



Well Construction Summary

Location: PS2-MW55
Personnel: J. Moore

Elevation: Ground Level ____
Top of Casing ____

DRILLING SUMMARY:

Total Depth 16.6'
Borehole Diameter 8"

Driller Mike (Bartholomew Bros.)

Rig Canterra 250
Bit(s) finger bit → hollow stem auger
Drilling Fluid none

Surface Casing below grd completion

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log
Casing String(s): C=Casing S=Screen

0.25 - 6.35	C1	
6.35 - 16.6	S1	

Casing: C1 2" PVC SCH 40
~~C2~~
~~C3~~
~~C4~~

Screen: S1 2" stainless steel
~~S2~~ 0.020" slot
~~S3~~
~~S4~~

Centralizers none

Filter Material 10-20 Colorado Silica sand
~~Cemen:~~ 1/4" Enviroplug bentonite pellets
Other Type I/II Portland Cement

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: 8"	10/30/88	0802	10/30/88	0856
Geophys. Logging:				
Casing: 2"	10/30	0900	10/30	0907
Filter Placement	10/30	0910	10/30	0942
Cementing	10/30	1000	10/30	1015
Bentonite Seal	10/30	0943	10/30	0948
Other:				

Comments:
Below ground flush mount well completion
H_2O 8.6' BGS

Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel

Source: SAIC, 1990

Borehole PS2-Mu

Log of Borehole

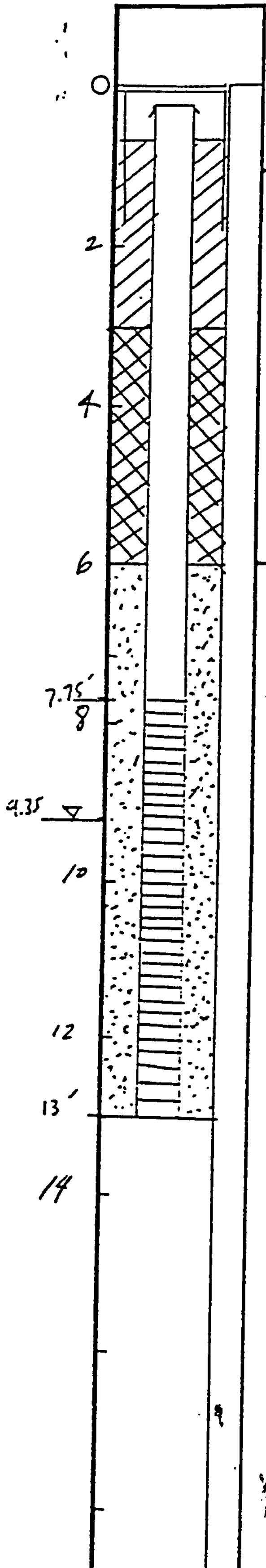
page 1 of 1

Project FAFB	Total Depth 13.0'	START / FINISH
Location PS-2 - MW56	Borehole Dia 8"	Date 10/30/88 / 10/30
Geologic Log by J. Moore	Depth to Fluid 9.35'	Time 1145 / 1243
Driller Mike (B. Brox)	Rig Canterra 150	How Left below grd
Geophysics by none	Bit(s) finger Bit	well completion
Weather Clear	Fluid	

Depth	Pene. Rate/ Blow Cts	~~Circulation Q (gpm)~~	ppm ~~OVA/~~ HNU hole	Sample #	Sample Inter-val	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0							0-.5' Asphalt	
							.5-3.0' Silty sand w/gravel (fill?)	
	8,13,10		1.2				3.0-3.5 Organic rich silt	
							w/minor fine gr. sand w/	
							mica 5Y 2.5/1 black (OL)	
							3.5-4.5 - Silty sand - med -	
							coarse gr., sub angular, qtz,	
							med. dense - v. sl. moist	
							5Y 4/2 olive gray (SM)	100%
	15,18,10		7.0				8.0-8.5 gravel sand clay	
							mixture, med-course gr sand,	
							w/ qtz, mica basalt, - poorly	
							sorted, sl. moist sl.	
							plastic 5GY 4/1 dk greenish	
							gray (GC)	
							8.5-9.0 - Gravel sand mix	
							w/ large - 2" clasts of basalt	70%
							(vesicular) - sand: v. coarse,	
							subangular, qtz, plag, minor	
							muscovite, & k-spar, saturated	
							w/ H_2O	
							13-14 Gravel sand mix -> sluff?	
							saturated w/ H_2O - very	
							course grained, subangular	
							sand - qtz, plag, k-spar, basalt,	
							mica, well sorted (GW)	

Hnu Background 0.6 ppm

Source: SAIC, 1990



Well Construction Summary

Location: PS2- MW56 Elevation: Ground Level ______

Personnel: J. Moore Top of Casing ______

DRILLING SUMMARY:

Total Depth 13.0'

Borehole Diameter 8"

Driller Mike (Bartholomew)

Rig CME Terra 150

Bit(s) finger bit - pilot hollow stem augers

Drilling Fluid none

Surface Casing below ground comp.

WELL DESIGN:

Basis: Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

-0.3 - 7.75	C1	
7.75 - 13.0	S1	

Casing: C1 2" PVC SCH 40

C2

C3

C4

Screen: S1 2" stainless steel

S2 0.020" slot

S3

S4

Centralizers none

Filter Material 10-20 Colorado Silica Sand

Cement Type I/II Portland

Other Enviroplug pellets Bentonite

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: 8"	10/30/93	1145	10/30/93	1245
Geophys. Logging:				
Casing: 2"	10/30	1308	10/30	1310
Filter Placement	10/30	1313	10/30	1337
Cementing:	10/30	1400	10/30	1410
Bentonite Seal:	10/30	1340	10/30	1345
Other:				

Comments: Below ground well completion H_2O @ 9.35' BGS

Key:

Bentonite

Cement/Grout

Sand Pack

Drill Cuttings

Gravel

Sand

Silt

Clay

Screen

Source: SAIC, 1990

Borehole MW-105

page 1 of 1

Log of Borehole

Project FAIRCHILD AFB	Total Depth 17.72 FT BGL	START / FINISH
Location OU1 - MW105	Borehole Dia 8-inch	Date 8-23-90 / 8-24-90
Geologic Log by Catherine Olsen	Depth to Fluid	Time 1618 / 0802
Driller Anderosa Drilling / Robbie Mills	Rig Mobile Drill B-80	How Left Flush
Geophysics by NA	Bit(s) Continuous Core Sample	Mounted protective
Weather 70°F, Sunny	Fluid None	Steel casing

Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	
0			B=2				0.0-1.0 FT: Sandy silt w/ organics,	
			H=1				fine roots, bslt clsts ≤ 30mm,	
							10YR 6/2, Fill	
							1.0-5.0 FT: Silty snd, fn to med,	
							poorly graded, mottled, 10YR 5/4 –	52
5							10YR 3/2, occas. ≤ 3 mm pebble	
				1	7.0-8.5		5.0-7.0 FT: v. crs snd, 10YR 5/4,	
			B=2				loose, occas > 50 mm bslt clst	
			H=1				7.0-8.0 FT: Crs snd w/ gravel,	
							QTZ, K-spar, Plag., well-graded,	50
10							10YR 5/1	
							9.0-17.0 FT: Sandy silt, v.	
							dry, weathered, fine to med	
							grain. Occas. ≤ 10 mm bslt	
15			B=2				clst. drilling becoming rough	
			H=2				and more difficult	
							T.D. = 17.72 FT	
20								

Source: SAIC, 1990

Borehole MW-106

page 1 of 1

Log of Borehole

Project	FAIRCHILD AFB
Location	OU-1-MW106 (FS-2)
Geologic Log by	Catherine Olsen
Driller	Fordenna Drilling / Robbie
Geophysics by	NA
Weather	72°F sunny
Total Depth	12.69 FT BGL
Borehole Dia	8-inch
Depth to Fluid	7.53 FT BGL
Rig	Mobile Drill B-90
Bit(s)	Continuous Core Sampler
Fluid	None

	START	FINISH
Date	8-24-90	8-24-90
Time	1054	1325

How Left: Flush Mounted Protective Steel casing

Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0			B=2 H=3				0.0-1.0 FT: Organic Silt w/ occas. ≤10 mm bslt clast, rndd to sub-rndd, 10YR 2/2, roots	
2							1.0-5.0 FT: Sandy Silt, med to course grn snd w/ QTZ, bslt, mica, K-spar, loose, dry, 10YR 2/2, Grayish soil @ approx 3.0 FT w/ fuel odor	
4			B=2 H=8					
	0.56			1	5.0-6.5			50
6			B=2 H=3				5.0-8.0 FT: Sandy Silt, med to course grn, subang to ang, dry, loose, mottled (10YR 7/1, 10YR 6/1, 10YR 6/6) light gray to gray areas have v. strong fuel odor	
8	Water Level @ 8.0 FT						8.0-10.0 FT: Basalt gravel, ≤20 mm, subrndd to subang, v. weathered, 20% clay, wet, loose, 10YR 3/2, occas > 50 mm basalt clast (weathered)	
10	0.83		C=200 B=2 H=300	2 3	10-11.5 10-11.5			50
							10.0-12.0 FT: No core collected. Drilling rough and uneven, weathered zone (?)	
12	0.13		B=2 H=10					20
							Bit Refusal at 12.7 FT	
							T.D. = 12.69 FT	

B = Background
H = Borehole
C = Core

Source: SAIC, 1990

Borehole MW-101

Log of Borehole

Project FAIRCHILD AFB	Total Depth 15.99 FT BGL	START / FINISH
Location OU1-MW109 (PS2)	Borehole Dia 8-inch	Date 8-27-90 / 8-27-90
Geologic Log by Catherine Olsen	Depth to Fluid	Time 1030 / 1315
Driller Anderson Drilling / Fairchild	Rig Mobile Drill F-80	How Left Flush
Geophysics by NA	Bit(s) Chisel Bit / Continuous Core	mounted Protective
Weather 71 °F. Sunny	Fluid None	Steel

Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0	0.07		B=Ø				0.0-0.33 FT: Asphalt (4.0")	
			H=Ø				0.5-3.0 FT: Fill Mat. (?), silty	
							snd coarse grain occas ≤15mm bslt	
							3.0-5.0 FT: Silty sand, course grn	
							v. sub to sbrang, well-sorted, Dry,	
							loose. 4.0-5.0 FT gray mod.	
							fuel odor. ≤40 mm bslt clast.	
							V. coarse sand. subang to ang.	
							wet	
5	0.63		B=Ø					50
			H=47	1	5.0-6.5		5.0-10.0 FT: sandy silt. fine	
			C=40	2 dup	5.0-6.5		to coarse grn, rndd to subang.	
							Basalt gravel. ≤40 mm 8.5-	
							10.0 FT wet, loose 2.5 Y 4/0	
	Water @ 8.0 FT						Strong fuel odor	
10			B=0.1					50
			H=72				10.0-15.0 FT: Basalt gravel,	
			C=150				silty ≤25mm v. wet loose,	
	0.03						2.5Y 4/0 (gray), At 11.5 ft color	
							change to 10YR 5/6 yellowish	
							brown basalt weathered —	
							(Core sample collected from 10.0	
							to 11.5 FT).	
							Bit refusal @ 15.9 FT	
15							TD = 15.99 FT	

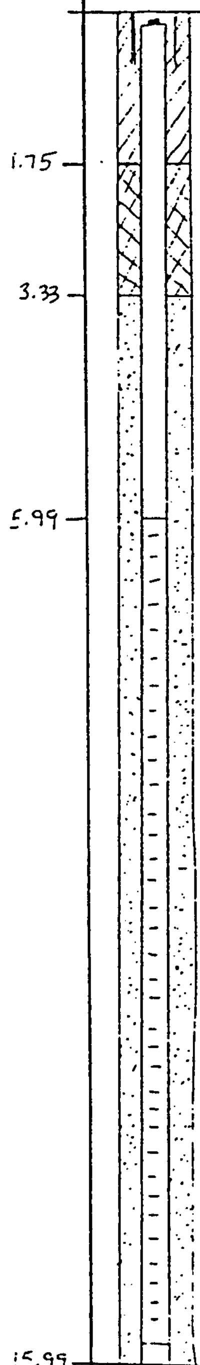
Source: SAIC, 1990

Well Construction Summary
(PS-2)

Flush Mounted

Location: OU1 - MW109 Elevation: Ground Level ____

Personnel: Catherine Olsen Top of Casing ____



DRILLING SUMMARY:

Total Depth 15.99 FT BGL

Borehole Diameter 8-inch

Driller Fordemen Drilling - Bobby Mills

Rig Mobile Drill B-80

Bit(s) Continuous Core Sampler

Drilling Fluid None

Surface Casing Protective Steel Flush Mounted

WELL DESIGN:

Basis: Geologic Log X Geophysical Log

Casing String(s): C=Casing S=Screen

0.0 - 5.99	C	
5.99 - 15.99	S	

Casing: C1 2-in dia. Sch 40 PVC
~~C2~~ Flush Threaded
~~C3~~
~~C4~~

Screen: S1 2-in dia Sch 40
~~S2~~ stainless steel
~~S3~~ Flush Threaded
~~S4~~ w/ 0.020" slots

Centralizers None

Filter Material 10-20 Colorado Silica Sand 3-100 lb sacks

Cement Portland Type I + II w/ powdered bentonite (3-94lb sacks)

Other [illegible] to [illegible] [illegible] 6" PVC casing Locking Cap

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	8-27-90	1030	8-27-90	1315
Geophys. Logging:				
Casing:	8-27-90	1501	8-27-90	1502
Filter Placement:	8-27-90	1505	8-27-90	1527
Cementing:	8-27-90	1605	8-27-90	1625
~~Development:~~ Bentonite Plug	8-27-90	1529	8-27-90	1535
Other: Flush Mount	8-25-90	1105	8-25-90	1120

Comments:

Key:
- Bentonite
- Sand
- Cement/Grout
- Silt
- Sand Pack
- Clay
- Drill Cuttings
- Screen
- Gravel

Source: SAIC, 1990

Borehole MW-110

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Log of Borehole

Project FAIRCHILD AFB	Total Depth 16.27 FT BGL		START / FINISH
Location OU1-MW110 (PS-2)	Borehole Dia 8-inch	Date	8-28-90 / 8-28-90
Geologic Log by Catherine Olson	Depth to Fluid	Time	0730 / 0910
Driller Ponderosa Drilling / Robbi Mills	Rig Mobile Drill B-87	How Left	Flush mounted Protective Steel
Geophysics by NA	Bit(s) Continuous Core Sampler		
Weather 80°F. Sunny	Fluid None.		

Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	
0	0.14						0-5 inches: Asphalt	
							0.6-5.0 FT: Sandy Silt, (40-	
							50% snd), crs grn, loose, dry,	
			B=0.1				Basalt Gravel ≤ 30mm. subrndd	
	0.63		H=7				10YR 4/2, sl. fel odor	50
5			C=5	1	5.0-6.5		5.0-10.0 FT: Sandy silt, fine	
							to crs grain, subrnd to subang.	
	Water Level @ 9.0 FT						mod. moist grading to saturated.	
			B=0.1				5Y 4/1	
	0.71		H=0.2	2	10.0-11.5			50
10			C=Ø				10.0-15.0 FT: Sandy silt w/	
							60-70% v. crs snd, rndd to	
							subang, saturated, loose,	
							occas. basalt clast ≤ 40 mm,	
			B=0.1				subrndd to subang, 5Y 4/0	50
15			H=0.1				15.0-16.0 FT: Basalt gravel ≤	
			C=Ø				45 mm, very weathered, fine	
							to crs snd subrnd to subang	
							minor clay (10%), 10YR 5/6,	
							mod. moist.	
20								
							T.D. = 16.27 FT BGL	

Source: SAIC, 1990

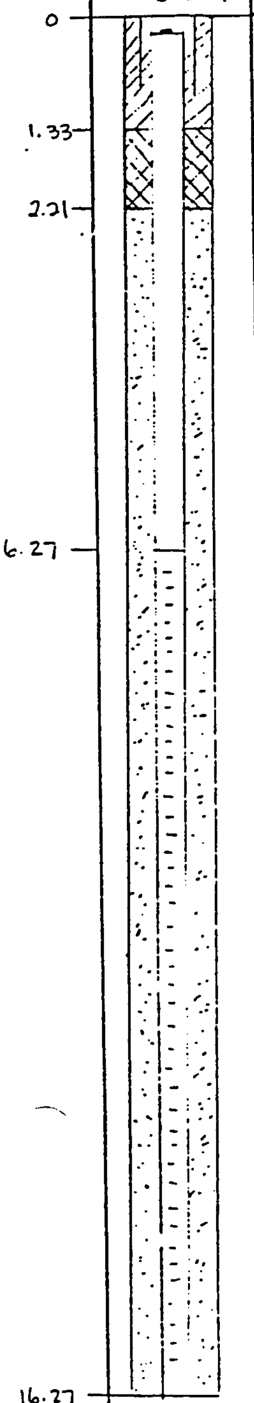
Well Construction Summary

(PS-2)

Location: NLI-MW110 Elevation: Ground Level ______

Personnel: Catherine Olsen Top of Casing ______

Flush Mount Protective Steel



DRILLING SUMMARY:

Total Depth 16.27 Ft EGL

Borehole Diameter 8-inch

Driller Ponderosa Drilling – [illegible] Mills

Rig Mobile Drill B-80

Bit(s) Continuous Core Sampler

Drilling Fluid None

Surface Casing [illegible]

WELL DESIGN:

Basis:

Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

0.0	6.27	C
6.27	16.27	S

Casing: C1 2-inch Sch. 40 PVC

~~C2~~

~~C3~~

~~C4~~

Screen: S1 2-inch Sch 40

~~S2~~ Stainless Steel

~~S3~~ [illegible]

S4 w/ 0.020" slots

Centralizers None

Filter Material 10-20 Colorado Silica Sand ([illegible])

Cement [illegible]

Other [illegible]

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	8-22-90	0830	8-22-90	0910
Geophys. Logging:				
Casing:	8-28-90	[illegible]	8-28-90	0947
Filter Placement:	8-28-90	0948	8-28-90	1036
Cementing:	[illegible]	1046	8-28-90	1059
~~Development:~~ Bentonite Fill	8-28-90	[illegible]	8-28-90	1041
Other:				
Flush Mount	8-20-90		8-20-90	

Comments:

- Sand pack settled out to 2.21 ft EGL

Key:

- Bentonite
- Cement/Grout
- Sand Pack
- Drill Cuttings
- Gravel
- Sand
- Silt
- Clay
- Screen

Source: SAIC, 1990

MW 176

Borehole Lac #3

Log of Borehole

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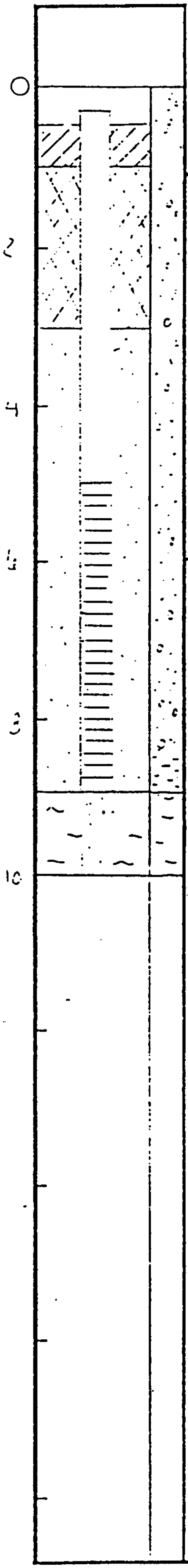
Project FAFB	Total Depth 10'	START / FINISH
Location PS 2	Borehole Dia 8"	Date 11-16-91 / 11-16-91
Geologic Log by G. Di Gregorio	Depth to Fluid 7'	Time 0826 / 0919
Driller Dan Claassen	Rig Mobile Drill B61	How Left grouted
Geophysics by NA	Bit(s) 8" Auger	flush mount well
Weather Foggy 25°F, breezy	Fluid NA	monument

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/HNU sample/ hole ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0							Coarse sand and gravel poorly sorted, ang, ≤ 20mm (mod basalt) greenish gray color	
2			45/45		0-1			25%
							Coarse sand w/ minor gravels ≤ 40mm, ang, mod sorted basalt, qtz & felds w/ greenish gray coloring	
4			45/45		2-4			75%
							Coarse sand & gravel ≤ 41mm ang, mod sorted, basalt, qtz & felds w/ greenish gray coloring	
6			95/35		4-6			75%
						∇	Coarse sand and gravel ≤ 20mm poorly sorted basalt qtz & felds free product @ 7' BGS black oil appearance	
8			120/111		6-8			75%
							silty sands and gravels ≤ 20 mm, ang, poorly sorted, to 8.4' grades to silty clay dark gray > 8.9 grades to clay w/ silt	
10			50/100		8-10		stiff plastic dense gray (free product) TD @ 8.9'	100%

Source: HNUS, 1993



Well Construction Summary

MW 176

Location: P52 ~~[illegible]~~ Elevation: Ground Level ____

Personnel: G. DiGregor[illegible] Top of Casing ____

DRILLING SUMMARY:

Total Depth 10'

Borehole Diameter 8"

Driller Dan Cl[illegible]
Environmental [illegible]

Rig Mobile Drill B[illegible]

Bit(s) 8" Auger

Drilling Fluid NA

Surface Casing NA

WELL DESIGN:

Basis:
Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

0.3 - 5		C
5 - 10		S

Casing: C1 Schedule 40 2" PVC
C2
C3
C4

Screen: S1 Sched 40 2" PVC
S2 0.02 slot
S3
S4

Centralizers N/A

Filter Material CST 10/20
Sand

Cement Portland Type II
5% bentonite gel

Other [illegible] bentonite pellets
[illegible]

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	11-11-91	0820	11-11-91	[illegible]
Geophys. Logging:				
Casing:	11-11-91	0920	11-11-91	0925
Filter Placement:	11-11-91	0930	11-11-91	0942
Cementing:	11-11-91	1015	11-11-91	1015
Bentonite Seal:	11-11-91	0944	11-11-91	0945
Other:				

Comments:
Hydrated bentonite w/ 5 gals of
potable water
Installed flush mounted well
monument

Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel

Source: HNUS, 1993

MW 177

Borehole Loc # 1

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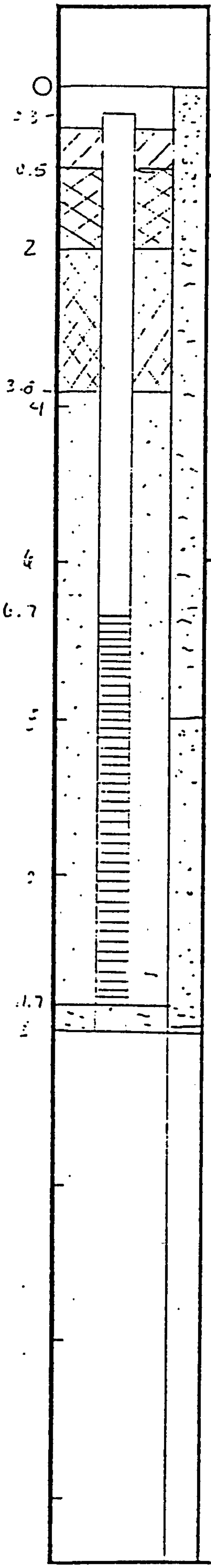
Log of Borehole

Project FAFB	Total Depth 12'	START FINISH
Location PSZ-	Borehole Dia 8"	Date 11-15-91 11-15-91
Geologic Log by G. DiGregorio	Depth to Fluid 8'	Time 1040 1203
Driller Dan Claussen/Envir. West	Rig Mobile Drill B61	How Left w/ flush
Geophysics by NA	Bit(s) 8" Auger	mount well monument
Weather overcast, 40°F foggy	Fluid NA	in place

Depth	Pene./Rate/Blow Cts	Circulation Q (gpm)	~~OVA/~~ HNU sample/hole	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0							gravels and sand poorly sorted ≤ 40 mm, ang. basalt & felds. Spoon refusal @ 1' auger cuttings color change from brown to gray @ 2"	
2			0/0		0-1			40%
							clay w/ lenses of sand coarse grain, well sorted, ang. basalt qtz & felds. strong fuel odor clay dark gray dense med plasticity - some grayish green lenses	
4			50/10		2-4			100%
							sandy clay med - coarse grain ang., poorly sorted, 20% - 50% sand, clay, dense stiff dry non plastic dark gray	
6			5/10		4-6			100%
						∇	clay w/ sands dark gray moist w/ fuel appearance (slick) grading to sand coarse grain @ 8' greenish gray	
8			180/80		6-8			25%
							coarse sand well sorted ang., basalt qtz & felds grayish green fluid wet @ 9' free product	
10			85/110		8-10			50%
							coarse sand w/ minor gravel well sorted, ang. basalt qtz & felds minor clay lenses stiff plastic greenish gray. 12'	
12			19/150		10-12		TD @ 11.7' BGS	15%

Source: HNUS, 1993



Well Construction Summary

Location: MW 177 PS 2 - [illegible] Elevation: Ground Level

Personnel: G. D. Gregory Top of Casing

DRILLING SUMMARY:

Total Depth 12'

Borehole Diameter 8"

Driller Don Claassen

Environmental [illegible]

Rig Mobile Drill 2 [illegible]

Bit(s) 6" Augers

Drilling Fluid NA

Surface Casing NA

WELL DESIGN:

Basis:

Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

0.3 - 6.7	C	
6.7 - 11.7	S	

Casing: C1 2" Schedule 40 PVC

C2

C3

C4

Screen: S1 2" schedule 40 PVC [illegible]

S2 [illegible] slot

S3

S4

Centralizers NA

Filter Material CS [illegible] Sand

16/30

Cement Portland Type I-II

Other Bentonite gel

Bentonite [illegible] plug

Bentonite pellets "3/8"

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
	11-15-91	[illegible]	[illegible]	[illegible]
Geophys. Logging:				
Casing:	11-15-91	[illegible]	11-15-91	[illegible]
Filter Placement	11-15-91	[illegible]	11-15-91	[illegible]
Cementing:	11-15-91	1303	11-15-91	1320
Bentonite Seal:	11-15-91	1324	11-15-91	[illegible]
Other:				
Hole plug	11-15-91	[illegible]	11-15-91	[illegible]

Comments:

Flush mount well monument

[illegible]

[illegible]

Key:

Bentonite

Sand

Cement/Grout

Silt

Sand Pack

Clay

Drill Cuttings

Screen

Gravel

Source: HNUS, 1993

MW 178 Borehole PS-2 ~~Loc 3~~

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Log of Borehole

Project FAIRCHILD AFB
Location PS-2 Loc 3BS
Geologic Log by Chuck Hout - SAIC
Driller Louis Hanner - Ponderosa
Geophysics by
Weather foggy - 30° - slight drizzle

Total Depth 32'
Borehole Dia 8"
Depth to Fluid 9-10'
Rig CP 7000
Bit(s) 8" tricone - 8" rock hammer bit
Fluid air/water

	START	FINISH
Date	11/6/91	11/6/91
Time	0850	0952

How Left water tight
flush surface monument
expanding plug w/o lock

	Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description
	0							4" asphalt base
0853	5							sand, med-coarse, some pebbles <20mm angular to subangular, basalt, quartz k-spar, mod sorted
								strong petro odor ~ 8'
0858	10						▽	sandy gravel - granules, angular, basalt
0905	15							gravel - granules to pebble < 30mm - mod sorted, angular to subangular - basalt - clay coating - fractured - heavily weathered basalt
								weathered basalt reddish brown subfaced Beginning to firm up
0919	20							Basalt - slightly fractured, trace weathering black 2.5/2 5Y
0936	25							Basalt massive - slightly fractured, trace weathering, 2.5/1 5Y
0947	30							Massive basalt - black 2/0 2.5Y
0952								Basalt as above
								TD 32' BGS

Source: HNUS, 1993

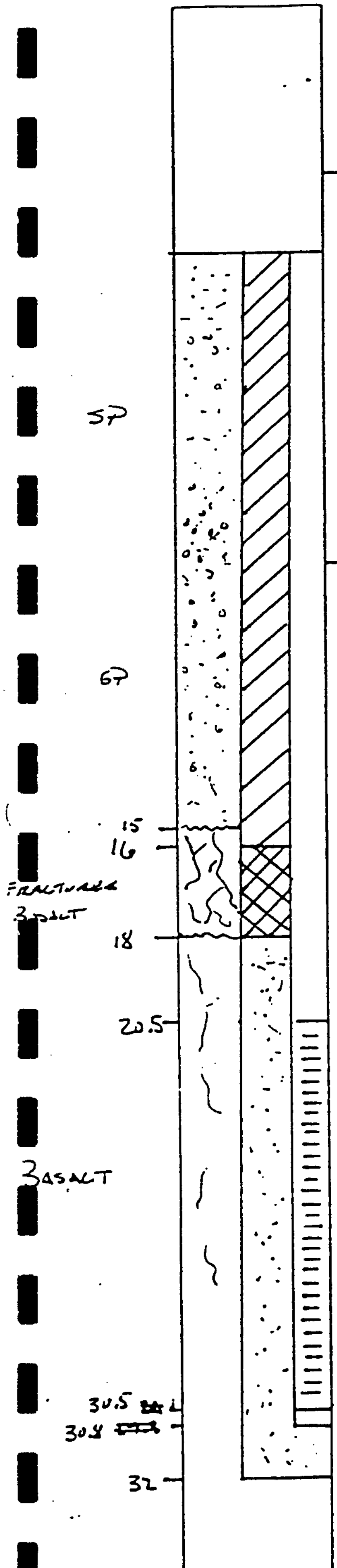
Well Construction Summary

Location: PS-2 Loo3 MW 178

Personnel: Chuck Houck - SAIC

Elevation: Ground Level

Top of Casing



DRILLING SUMMARY:

Total Depth 32'

Borehole Diameter 8"

Driller Louie Hanner - Ponderosa

Rig CP 7000

Bit(s) 8" Tricone / 8" Rock hammer

Drilling Fluid Air/water

Surface Casing 8" steel +3-1ft

WELL DESIGN:

Basis:

Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

From	To	Type
30.8	30.5	C
30.5	20.5	S
	0	C

Casing: C1 4"x4" PVC end cap

C2 4" sch 40 PVC

C3

C4

Screen: S1 4" sch 40 PVC 020 slot

S2

S3

S4

Centralizers None

Filter Material 10-20 silica sand

Cement Portland I-II + 5% bentonite

Other annular seal - 3/8" bentonite pellets

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: Air Rotary	11/6/91	0850	11/6/91	0957
Geophys. Logging:				
Casing:	11/6/91	1020	11/6/91	1030
Filter Placement:	11/6/91	1030	11/6/91	1045
Cementing:	11/6/91	1150	11/6/91	1155
Development:				
Other: Pull casing	11/6/91	1045	11/6/91	1150
Set surface monument	11/6/91	1150	11/6/91	1250

Comments:

Key:

Bentonite

Sand

Cement/Grout

Silt

Sand Pack

Clay

Drill Cuttings

Screen

Gravel

Source: HNUS, 1993

MW 179 Borehole PS-2 ~~loc 2~~

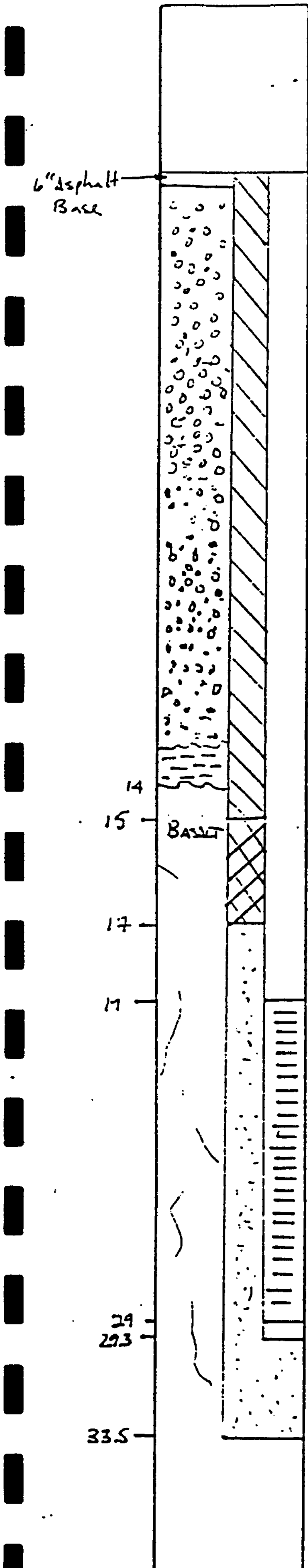
page 1 of 1

Log of Borehole

Project FAIRCHILD AFB	Total Depth 33.5	START FINISH
Location PS-2 · ZOC ZABR	Borehole Dia 8"	Date 11/5/91 11/5/
Geologic Log by CHUCK Houck - SAIC	Depth to Fluid 11'	Time 0822 1003
Driller Louie Hanner PONDEROSA	Rig CP 7000	How Left flush surface
Geophysics by	Bit(s) 8" TRICONE / 8" rock hammer bit	monument w/
Weather 30° drizzle	Fluid AIR/WATER	expanding plug w/o lock

Time	Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description
	0							
0825	5					5	GP	Gravel, tr coarse sand, pebbles < 30 mm, angular to sub angular mod sorted, basalt quartz, K-spar
0828	10			strong petro odor		10		gravel, granule to pebbles < 20 mm, basalt tr quartz, sub angular to subrounded
							SM	Silty sand, fine-coarse, poorly sorted
0830	15						BR	Basalt - slightly fractured - trace weathering @ 14
0848	20							Massive basalt - slightly fractured trace weathering -
0915	25							Massive basalt - black - trace weathering
0932	30							Basalt as above
0958								Basalt as above - TD BORING 33.5

Source: HNUS, 1993



Well Construction Summary

Location: PS-2 ~~ZABR~~ MW179 (19)

Elevation: Ground Level ______

Personnel: Chuck Houck - SAIC

Top of Casing ______

DRILLING SUMMARY:

Total Depth 33.5

Borehole Diameter 8"

Driller Louie Harmen - Ponderosa

Rig CP 7000

Bit(s) Tricone / Rock Hammer

Drilling Fluid Air/Water

Surface Casing 8" steel + 3-14

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

29.3 - 29	C	
29 - 19	S	
19 - 0	C	

Casing: C1 4" x 4" PVC end cap
C2 4" sch 40 blank casing
C3
C4

Screen: S1 4" PVC sch 40 slot 020
S2
S3
S4

Centralizers None

Filter Material 10-20 silica sand

Cement Portland Type II + 5% bentonite

Other annular seal - 3/8" bentonite pellets

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: Air Rotary	11/5/91	0822	11/5/91	1000
Geophys. Logging:				
Casing:	11/5/91	1030	11/5/91	1045
Filter Placement:	11/5/91	1045	11/5/91	1100
Cementing:	11/5/91	1115	11/5/91	1145
Development:				
Other: monument installment includes site cleanup	11/5/91	1230	11/5/91	1350

Comments:

Key:

- Bentonite
- Cement/Grout
- Sand Pack
- Drill Cuttings
- Gravel
- Sand
- Silt
- Clay
- Screen

Source: HNUS, 1993

MW1180

Borehole PS-2 [illegible]

Log of Borehole

Project FAIRCHILD AFB	Total Depth 62	START / FINISH
Location PS-2-Loc+ ~~[illegible]~~	Borehole Dia 8	Date 11/3/91 / 11/3/91
Geologic Log by Chuck Houck SAIC	Depth to Fluid	Time 1230 / 1930
Driller Louie Hunner - PONDEROSA	Rig CP 7000	How Left flush
Geophysics by	Bit(s) 8" TRICONE	surface monument
Weather overcast 20°	Fluid AIR/WATER	w/expanding end plug [illegible]

	Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description
	0							
	5			0		5		silty sand, some granules, fine to coarse poorly sorted, dk gray brown
1240	10			0		10		sandy silt, dk gray - black, v fine sands
1242	15			0		15	GP	~~sandy~~ gravel, pebbles (<10mm) + granules - some coarse sand, ~~[illegible]~~ subangular to rounded, basalt, blk
1246	20			0		20	CL	sandy clay, gray brown, fine sand soft
1301	25			0		25	Bedrock highly fractured	gravelly sand, ~~some~~ tr clay, f-coarse, poorly sorted, red, 4/3 2.5YR - very weathered basalt, angular Bedrock?
	30			0		30		No sample

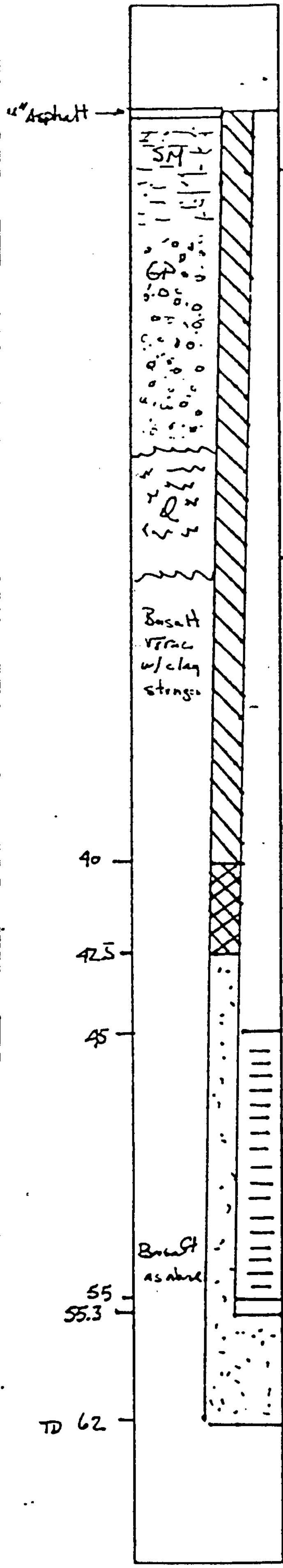
Source: HNUS, 1993

Log of Borehole

Project FAIRCHILD AFB	Total Depth 62	START FINISH
Location PS-2 ~~[illegible]~~ MW180	Borehole Dia 8"	Date 11/3/91 11/3
Geologic Log by Chuck Houck - SAIC	Depth to Fluid	Time 1230 1930
Driller Louie Hanner - Ponderosa	Rig CP-8000	How Left Surface
Geophysics by	Bit(s) 8" TRICONE	monument w/ expand-
Weather overcast - 20°F	Fluid AIR/WATER	end plug w/o lock

Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description
0							
35			0		35		Basalt - weathered - fractured w/ sandy clay, yellowish brown, fine sands
1305 40			0		40		Basalt - fractured, highly weathered
1315 45			0		45		Basalt - very angular, fractured, highly weathered, interbedded yellow clays.
1318 50			0		50		no change
1320 55			0		55		Basalt as above
1325 60			0		60		Basalt as above TD 62

Source: HNUS, 1993



Well Construction Summary

MW 180

Location: PS-2 Lot BR

Elevation: Ground Level ______

Personnel: Chuck Houck - SAIC

Top of Casing ______

DRILLING SUMMARY:

Total Depth 62

Borehole Diameter 8"

Driller Louie Hanna - PONDEROSA

Rig CP 7000

Bit(s) 8" TRICONE

Drilling Fluid AIR/WATER

Surface Casing 8" R-17

WELL DESIGN:

Basis:

Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

55.3	55	C
55	45	S
45	0	C

Casing: C1 4"x4" threaded PVC end cap

C2 4" sch 40 PVC

C3

C4

Screen: S1 4" sch 40 PVC 020 slot

S2

S3

S4

Centralizers None

Filter Material 10-20 silica sand

Cement PORTLAND I-II + 5% bentonite

Other annular seal - 3/8" bentonite pellets

CONSTRUCTION TIME LOG:

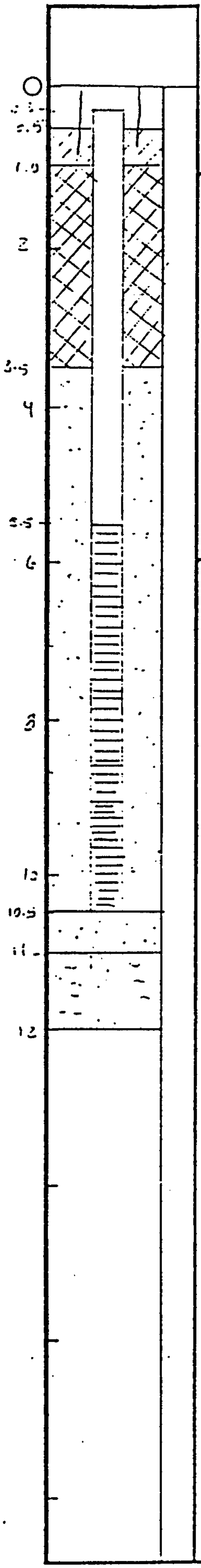
Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: AIR ROTARY	11/3/91	1230	11/3/91	1350
Geophys. Logging:				
Casing:	~~1350~~ 11/3/91	1450	11/3/91	1500
Filter Placement:	11/3/91	1500	11/3/91	15~~25~~
Cementing:	11/3/91	1515	11/3/91	1600
Development:				
Other: set monument	11/8/91	~~1500~~ 1630	11/3/91	1800

Comments:

Key:

- Bentonite
- Cement/Grout
- Sand Pack
- Drill Cuttings
- Gravel
- Sand
- Silt
- Clay
- Screen

Source: HNUS, 1993



Well Construction Summary

Location: MW15 [illegible]

Personnel: G. D. Gregoric

Elevation: Ground Level ______

Top of Casing ______

DRILLING SUMMARY:

Total Depth 12'

Borehole Diameter 8"

Driller Dr. Classic / Environmental [illegible]

Rig Mobile Drill B61

Bit(s) 8" Augers

Drilling Fluid NA

Surface Casing NA

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	11-14-91	0810	11-14-91	0840
Geophys. Logging:				
Casing:	11-14-91	0915	11-14-91	0915
Filter Placement	11-14-91	0917	11-14-91	0931
Cementing:	11-14-91	1020	11-14-91	1024
Bentonite Seal:	11-14-91	0932	11-14-91	[illegible]
Other:				

WELL DESIGN:

Basis:
Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

0.5 - 5.5	C1	
5.5 - 10.5	S1	

Casing: C1 Schedule 40 2" PVC
C2
C3
C4

Screen: S1 Schedule 40 2" PVC .020 slot
S2 [illegible]
S3
S4

Centralizers NA

Filter Material CSI Sand 10/20

Cement Pellets

Other [illegible] 4" [illegible] bentonite chip plug

Comments:
Hydrated bentonite w/ 5 gals of potable water
Installed flush mount well monument.

Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel

Source: HNUS, 1993

BORING LOG | **NUS CORPORATION**

PROJECT: FAEB | BORING NO. SB001, PS-2

PROJECT NO.: 3286 | DATE: 10/31/91 | DRILLER: THERON L / BARTH

ELEVATION: | FIELD GEOLOGIST: FRED W RANSFR

WATER LEVEL DATA:

(Date, Time & Conditions) 10/31/91 9:49 OVER CAST COLD 35°F BREEZY

SAMPLE NO. & TYPE OR RQD	① DEPTH (Ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth,Ft.) OR SCREENED INTERVAL	MATERIAL DESCRIPTION: SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS
							ASPHALT ≈6"		(HNU)
✓ S-1 1010		49 24 / 24			MED DENSE			GM	S-1 (0.8)
	2	49 / 49	1.5 / 2.0			GRAY GRN	SILT, WELL GRADED SAND w/some GRAVELS GRAVELS ≤1/4" DIA. SUBROUNDED		TR CLAY MOIST
S-2 1017		17 / 20			MED DENSE	D-GRN	CLAY SILT WELL GRADED SAND w/some GRAVEL ≤1.5" DIA	SW	S-2 (0.0) MOIST
	4	13 / 21	1.5 / 2.0						
S-3 1025		17 / 17			SOFT	D-GRN	SILT CLAY some sands and fine gravel	ML	S-3 (0.4)
	6	50/5"	.9 / 1.0						SPOON REFUSAL SATURATED 5.9
	8						TD = 4' SAMPLED TO 6'		
							H_2O @ 5.9		
	10								

REMARKS CANTERA RIG 4¼" ID HSA, 2½" S.S. w/BRASS INSERTS 140lb HAMMER DROPPED 30"

① ZERO DEPTH @ 6" BELOW ASPHALT TOP SURFACE

BORING SB001

PAGE 1 of 1

* SAMPLES CAPPED ARE INDICATED BY A CHECK MARK

CIRCLED SAMPLE = INDICATES SAMPLE SENT TO LAB FOR ANALYSIS

Source: HNUS, 1993

BORING LOG WOODY | NUS CORPORATION

PROJECT: FAFB
PROJECT NO.: 3286
ELEVATION:
WATER LEVEL DATA:
(Date, Time & Conditions) 11/1/91 CLEAR COLD 32° WINDY 1430

DATE: 11/1/91
FIELD GEOLOGIST: FRED WRANSCR

BORING NO. SB002 PS2
DRILLER: THEROU L. / BARTLI BROS

SAMPLE NO & TYPE OR ROD	DEPTH (Ft) OR RUN NO.	BLOWS 6" OR ROD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft.) OR SCREENED INTERVAL	SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS SPLIT SPOON HNU → PPM
							ASPHALT ≈6" BASE ≈1.5'		
	2								
S-1 1437		37 28			DENSE	GRN	CLAYEY SILT SOME SAND & SILT TR GRAVEL ±.5"	SC	S-1 SLIGHTLY MOIST FUEL ODOR (50.
	4	47 48	1.4 / 2.0						
S-2 1448		7 7			Loose to MED DENSE	D-GRN	AS ABOVE	SC	S-2 SLIGHTLY MOIST FUEL ODOR (90.0
	6	10 14	1.3 / 2.0						
S-3 1500		18 18			MED DENSE TO LOOSE	D-GRN	GRADED SAND w/some SILT + GRAVEL TR/CLAY	SW-SM	S-3 MOIST FUEL ODOR (140.0
	8	15 9	.5 / 2.0						
S-4 1507		2 4			Loose to MED DENSE	BLK D-GRN	SILTY CLAY TR GRADED SAND	CL	S-4 WET FUEL ODOR (140.0
	10	15 18	1.5 / 2.0						
S-5 1521		5 8			LOOSE	BLK D-GRN	SILTY CLAY SOME FINE SAND	CL	S-5 SATURATED (100.0)
	12	8 12	1.5 / 2.0						
							TD = 10' SAMPLE TO 12		
							5 SPOONS H_2O @ 10.5		

REMARKS CANTERA RIG 4¼ HSA 2½ S.S. w/BRASS INSERTS, 140 lb HAMMER DROPPED 30"

BORING SB002 PS

PAGE 1

✗ CAPPED INSERTS ARE INDICATED BY A CHECK MARK
CIRCLED SAMPLE # INDICATES SAMPLE SENT TO LAB FOR ANALYSIS

Source: HNUS, 1993

BORING LOG — NUS CORPORATION

PROJECT: FAFB
BORING NO: SB 003 - PS2
PROJECT NO.: 3286
DATE: 11/3/91
DRILLER: THERON L. / BAZT HOLCOM
ELEVATION:
FIELD GEOLOGIST: P. NIMMER
WATER LEVEL DATA:
(Date, Time & Conditions) 11/3, 08:33 30°F., Cloudy.

SAMPLE NO. & TYPE OR ROD	DEPTH (FT) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, Ft.) OR SCREENED INTERVAL	SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS SPLIT SPOON HNU
✓ S-1 0845		— / 44			DENSE	GREY	Sandy SILT Some CLAY		S-1 DRY (<1 PP
	2	44 / 44	1.2 / 2.0						
S-2 0900		50 / 55			DENSE	GREY	Sandy SILT Some organic material		S-2 DRY (0 PPM
	4	37 / 37	1.5 / 2.0						
✓ S-3 0910		13 / 12			MED. DENSE	GREY	SANDY SILT		S-3 DUP (0 PPM
	6	20 / 25	2.0 / 2.0						
S-4 0915		12 / 12			MED DENSE	GREY	CLAYEY SILT		MOIST (0 PPM
	8	12 / 11	1.5 / 2.0						
S-5 0920		3 / 3			VERY loose to loose	GREY	CLAYEY SILT		Fuel odor Sat. @ 9' (15 PPM
	10	5 / 5	1.5 / 2.0						
							TD = 8' SAMPLED TO 10'		
							H_2O @ 9.0' 09.30		

REMARKS: CANTERA RIG 4 1/4 H.S.A., 2 1/4 ID SPLIT SPOONS with Brass inserts.
140 lb Hammer drop 30 inches.
Asphalt 6" Thick.

BORING SB 003-PS

PAGE ___ : ___

(*) Capped inserts indicated by ✓.

Source: HNUS, 1993

BORING LOG — NUS CORPORATION

PROJECT: FAFB — BORING NO SB004 - PSD
PROJECT NO.: 3286 — DATE: 11/3/91 — DRILLER: THERON L. / BATT BROS.
ELEVATION: — FIELD GEOLOGIST: P. NIMMER/FREDW. RSLUSER
WATER LEVEL DATA:
(Date, Time & Conditions) 11/3/91 0945 30°F, CLOUDY

SAMPLE NO. & TYPE OR ROD	DEPTH (Ft.) OR RUN NO.	BLOWS 6" OR ROD (%)	SAMPLE RECOVERY / SAMPLE LENGTH	LITHOLOGY CHANGE (Depth/Ft.) OR SCREENED INTERVAL	SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS SPLITSPOON HNU (ppm)
S-1 0954		— / 40			DENSE		ASPHALT 6" WELL GRADED SAND SOME SILT TR CLAY + GRA	SW	GRA ≤.5" (0.0)
	2	40 / 40	1.0 / 1.5						
S-2 1000		36 / 27			MED DENSE to DENSE	BRN	WELL GRADED SAND SOME SILT + CLAY + GRA. GRA ≤ 2"	SW	S-2 MOIST (4.0)
	4	27 / 38	1.5 / 2.0						
S-3 1009		23 / 26			MED DENSE	BRN BLK	CLAYEY SILT SOME GRADED SAND	ML	S-3 MOIST (0.2)
	6	15 / 13	1.4 / 2.0						
S-4 1017		5 / 10			LOOSE	BLK	SILTY CLAY W/ORGANICS	OL	S-4 MOIST (0.0) WET AT 7.9'
	8	10 / 10	1.5 / 2.0						
S-5 1020		7 / 7			LOOSE	BLK to GRN	Clay, BLK at 8.5; gray ~ 9.0, Green Some silt at 9.5'	CH	Saturated at 8.5
	10	7 / 8	1.5 / 2.0						
							TD = 6"		2 HSA down ~ ~e
							SD = 10' STOPPED AT 10:24		ACTO 6'. DID NOT NEED
							Sat. @ 8.5'		TO AUGER FROM 6' to 8

REMARKS CFTER A RIG 4¼ H.S.A. 2¼ ID SPLITSPOON w/ BRASS INSERTS. 140 lb HAMMER DROP 30 inches. Asphalt 6" thick

COMPOSITE SAMPLE

(*) CAPPED INSERTS INDICATED BY ✓.

BORING SB004-PSD

PAGE ___

Source: HNUS, 1993

BORING LOG — **NUS CORPORATION**

PROJECT: FAFB BORING NO: SB005 - PS2
PROJECT NO.: 3286 DATE: 11/3/91 DRILLER: THERON L. / BAET BROS
ELEVATION: FIELD GEOLOGIST: P. NIMMER / F. RAMSER
WATER LEVEL DATA:
(Date, Time & Conditions) 11/3/91 10:45 35° F, CLOUDY

SAMPLE NO & TYPE OR RQD	DEPTH (Ft) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft.) OR SCREENED INTERVAL	MATERIAL DESCRIPTION: SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS SPLITSPOON HNu
S-1 10:55		– / 42			DENSE	BLK	ASPHALT ≈ FIRST 6" SILT AND FINE SAND	ML	DRY (0.5
	2	42 / 42	1.5 / 2.0						
S-2 11:00		23 / 23			MED. DENSE	BRN	CLAYEY SILT, SOME GRAVEL AND SAND at near 2 - 3'	CL	MOIST (4 PP
	4	36 / 23	1.6 / 2.0						
S-3 11:15		8 / 13			LOOSE to MED DENSE	BRN - GRN	SILTY CLAY, SOME SAND.	ML	MOIST. (0-5
	6	50	1.3 / 1.5						REFUSAL AT 5.5'

FINISH TIME: 11:22
TD: 5.5 SD: 5.5
H_2O @: —

REMARKS: CANTERA RIG 4 1/4, 2 1/4 ID SPLIT SPOON w/ BRASS INSERTS.
140 lb HAMMER DROP 30 INCHES.
ASPHALT ≈ 6' THICK

BORING SB005-PS2
PAGE ___ : ___

(*) CAPPED INSERTS INDICATE B.I ✓

Source: HNUS, 1993

BORING LOG NUS CORPORATION

PROJECT: FAFB BORING NO. SB006 P-2

PROJECT NO.: 3286 DATE: 11/1/91 DRILLER: THERON L./BART BROS.

ELEVATION: FIELD GEOLOGIST: FRED W. RAMSER

WATER LEVEL DATA:

(Date, Time & Conditions) 11/1/91 1100 CLEAR COLD 30°F WINDY

SAMPLE NO & TYPE OR RQD	DEPTH (ft) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft) OR SCREENED INTERVAL	SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS SPLITSPOON HNU → (ppm)
						BRN	ASPHALT ≈6" THICK BASE ≈1.5' THICK SILTY SAND	SM	
	2					D-BRN	SILT SAND		
✓ S-1 1111	4	17 / 39 / 47 / 27	1.5 / 2.0				SILTY SAND w/some CLAY & GRAVEL	SP	S-1 (DUPLICATE) SLIGHTLY MOIST (0.1)
✓ S-2 1120	6	9 / 13 / 15 / 19	1.5 / 2.0		STIFF	BLK	SILTY CLAY w/some SAND	CL	S-2 MOIST (5.0)
✓ S-3 1135	8	4 / 6 / 6 / 7	1.3 / 2.0		STIFF	BLK	AS ABOVE	CL	S-3 MOIST (25)
S-4 1140		5 / 15 / 7 / 17	1.7 / 2.0				AS ABOVE	CL	S-4 SATURATED @ 9' (5
						GRN	GRADED SAND @ 9.5 TO 10.0'	SW	
							TD = 8' SAMPLED TO 10'		
							H_2O @ 9'		

REMARKS CANTERA RIG 4 1/4" HSA, 2 1/4" S.S. w/BRASS INSERTS, 140 lb HAMMER DROPPED 30"
NOTE @ 6' MEASURED 25 ppm @ HEAD SPACE IN AUGER, MEASURED 0.0 ppm @ B.Z.
(GOOD WINDS)

BORING SB006 PS2

PAGE 1

* CAPPED INSERTS ARE INDICATED WITH A CHECK MARK

CIRCLED SAMPLE # INDICATES SAMPLE SENT TO LAB FOR CHEMICAL ANALYSIS

Source: HNUS, 1993

BORING LOG	NUS CORPORATION

PROJECT: FAFB
BORING NO. SB007 PS-2
PROJECT NO.: 3286
DATE: 10/31/91
DRILLER: THERON L. / BART. BROS
ELEVATION:
FIELD GEOLOGIST: FRED URAMSER
WATER LEVEL DATA:
(Date, Time & Conditions) 10/31/91 10 45 OVERCAST, FLURRIES COLD 35°F

SAMPLE NO & TYPE OR RQD	① DEPTH (FT) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft.) OR SCREENED INTERVAL	MATERIAL DESCRIPTION: SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	MATERIAL DESCRIPTION: COLOR	MATERIAL DESCRIPTION: MATERIAL CLASSIFICATION	USCS	REMARKS
							ASPHALT ≈ 6"		
S-1 10 52		17 / 20			VERY DENSE	GREY	SAND, SILT, FINE GRAVELS ≤.5" dia	SP	S-1 (22 ppm) MOIST
	2	41 / 49	1.1 / 2.0				TR CLAY		
S-2 11 10		27 / 50/1"			VERY DENSE	GRN GREY	CLAYEY SILT w/some GRADED SAND TR GRAVEL ≤1.5 dia SUBROUND TO	SC	S-2 2'-2.5' 88 ppm
	4	50/4"	.7 / 2.0				ANGULAR AS ABOVE		AUGER 6" HAMMER SPOON @ 2.5 STILL SPOON REFUSAL, AUGER ADVANCED
S-3 11 24	4.5	17 / 17			STIFF	D-GRN	CLAY, SOME SILT + GRADED SAND	CL	S-3 6" AUGER AWAY, AUGERED (1.5 TO 4.5" HAMMER S.S.
	6	18 / 20	1.5 / 2.0						S-3: 4.5-6.5 MOIST
S-4 11 35		8 / 9			MED DENSE	D-GRN	GRADED SAND w/SOME SILT + CLAY	SP	S-4 6.5-8.5 SATURATED (TOO) @ 8.4
	8	11 / 10	1.0 / 2.0						
							TD = 6.5 SAMPLED TO 8.5"		
							H_2O @ 8.4		
							COMPLETED AT 11.40		

✓ (beside S-1)
TWO S.S. REF. (beside S-2)

REMARKS CANTERA RIG 4¼ HSA 2½" ID S.S. w/BRASS INSERTS
SB007 COMPOSITE SAMPLE
① ZERO DEPTH @ 6" BELOW ASPHALT TOP SURFACE

BORING SB007 PS-
PAGE 1 of 1

✓ CAPPED INSERTS ARE INDICATED BY A CHECK MARK
CIRCLED SAMPLE # INDICATES SAMPLE SENT TO LAB FOR CHEMICAL ANALYSIS

Source: HNUS, 1993

BORING LOG . NUS CORPORATION

PROJECT: FAFB BORING NO SB008, PS2

PROJECT NO.: 3286 DATE: 11/1/91 DRILLER: THERON L. / BARTH BROS.

ELEVATION: FIELD GEOLOGIST: FRED W. PARKER

WATER LEVEL DATA:

(Date, Time & Conditions) 11-1-91 0755 COLD 28°F WINDY CLEAR

SAMPLE NO. & TYPE OR RQD	DEPTH (FT) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft.) OR SCREENED INTERVAL	SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS
							ASPHALT ≈ 6"		SPLIT SPOON - HNU - Ipm
S-1 1005		50 / 50/6"			DENSE	BRN	SAND w/ some SILT + GRAVEL ±.5"	SW	S-1 (0.5) SLIGHTLY MOIST
	2		1.0 / 1.0						
S-2 1015		60 / 70/6"			DENSE	D-BRN	SILTY CLAY w/ some SAND TR/GRAVEL ±.5"	CL	S-2 SLIGHTLY MOIST (0.5)
	4		0.9 / 1.0						
S-3 1030		8 / 9			STIFF	BLK	SILTY CLAY TR SAND + GRAVEL	CL	S-3 MOIST (5
	6	9 / 12	1.3 / 2.0						
S-4 1040		12 / 12			STIFF	D-GRN	CLAYEY SILT w/ some SAND + GRAVEL	MH	S-4 SATURATED AT 7.9 (5
	8	12 / 12	1.5 / 2.0		MED DENSE	GRN	GRADED SAND @ 7.5 TO 8.0'	SP	
							TD = 6" SAMPLED TO 8'		
							H_2O @ 7.9'		

REMARKS CANTERA RIG 4¼" HSA, 2½" S.S. w/ BRASS INSERTS 140 LB HAMMER DROPPED 30"

① ZERO DEPTH @ 6" BELOW ASPHALT TOP SURFACE

BORING SB008

PAGE 1

* CAPPED INSERTS ARE INDICATED BY A CHECK MARK

CIRCLED SAMPLE # INDICATES SAMPLE TO BE SENT FOR ANALYSIS

Source: HNUS, 1993

BORING LOG | **NUS CORPORATION**

PROJECT: FAFB | BORING NO SB009 PS-2

PROJECT NO.: 328G | DATE: 10-31-91 | DRILLER: Therou L. / Bartholomew

ELEVATION: | FIELD GEOLOGIST: Fred W Parker

WATER LEVEL DATA:

(Date, Time & Conditions) 10/31/91 1340 OVERCAST 32° BREEZY

SAMPLE NO & TYPE OR ROD	① DEPTH (FT) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft.) OR SCREENED INTERVAL	MATERIAL DESCRIPTION: SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS (Background HNu =)
							ASPHALT ≈ 6"		SPLIT SPOON
S-1 1355		17 / 46			V STIFF TO HARD				S-1 (2-
	2	48 / 49	1.0 / 2.0			GREY BRN	SILTY GRADED SAND SOME GRAVEL TR CLAY	SW	
S-2 1405		18 / 36			V STIFF TO HARD	D.GRY	SILTY CLAY w SOME GRADED SAND + GRAVEL GR ≤ 1.5" dia	CL	S-2 AUGER REFUSAL @ 2' MOVED 3' TOWARD BLDG.
	4	50/2"	0.9 / 1.2						S-2, 2-3.2 (0.
S-3 1410		5 / 5			STIFF	BLK	SILTY CLAY TR/GRADED SAND 5-5.5'	CL	S-3 MOIST TR/ORGANICS (5-
	6	6 / 10	1.2 / 2.0			GRN BLK	GRADED SAND + SILT 5.5'-6.0'	SM	
S-4 1430		6 / 6			MED STIFF TO STIFF	GRY	GRADED SAND + SILT w/some GRAVEL ≤ .5"	SM	S-4 SATURATED @ 7.5 6.
	8	8 / 12	1.2 / 2.0						
							TD = 6 SAMPLED TO 8.0'		
							H_2O @ 7.5		

REMARKS CANTERA RIG 4¼" ID HSA, 2" S.S. w/ BRASS INSERTS, 140 lb HAMMER DROPPED 30"

@ 4' HS @ GROUND LEVEL = 25 ppm

@ 4' B.Z. 0.0 ppm, GOOD BREEZE

① ZERO DEPTH @ 6" BELOW ASPHALT TOP SURFACE

BORING SB009

PAGE 1 of 1

* CAPPED INSERTS ARE INDICATED BY A CHECK MARK

CIRCLED SAMPLE # INDICATES SAMPLE SENT TO LAB FOR ANALYSIS

Source: HNUS, 1993

BORING LOG NUS CORPORATION

PROJECT: FAFB BORING NO ~~S800~~ SB010 PS2

PROJECT NO.: 3286 DATE: 11-1-91 DRILLER: THERON L. BART. BROS.

ELEVATION: FIELD GEOLOGIST: FRED WRAMSER

WATER LEVEL DATA:

(Date, Time & Conditions) 11-1-91 755 CLEAR, COLD 32° BREEZY

SAMPLE NO. & TYPE OR RQD	① DEPTH (ft) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY / SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft) OR SCREENED INTERVAL	SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS	REMARKS
							ASPHALT ≈ 6"		Background HNU <0.6 ppm; SPLIT SPOON HNU = (ppm)
S-1 0820		39 / 18							S-1
	2	20 / 20	1.9 / 2.0		MED DENSE	BRN	SILTY GRADED SAND w/some CLAY TR/GRAVEL	SM	GRAVEL ≤ 1.5" dia SLIGHTLY MOIST (0.2
S-2 0830		17 / 20				D.BRN	SILTY CLAY w/some GRAVEL ≤ 1.5" dia [illegible]	CL	S-2 TR/ORGANICS SLIGHTLY MOIST (0.[illegible]
	4	27 / 28	1.4 / 2.0						
S-3 0845		17 / 20			MED-D STIFF	D.BRN	SILTY GRADED SAND w/some CLAY 5.5-6; SILTY CLAY (4.5 to 5.5) TR/SAND & GRAVEL ≤ 1.0" dia	SM - CL	S-3 MOIST; SLIGHTLY MOIST (0.0
	6	22 / 24	1.5 / 2.0						
S-4 0900		16 / 16			MED DENSE		GRADED SAND w/some SILT TR/CLAY	SM	S-4 SATURATED @ 7.5' (0.2
	8	16 / 10	1.5 / 2.0						
							TD = 6 SAMPLED to 8'		
							H_2O @ 7.5'		

REMARKS CANTERA RIG 4¼" HSA, 2¼" S.S. w/BRASS INSERTS, 140 lb HAMMER DROPPED 30"

① ZERO DEPTH @ 6" below ASPHALT TOP SURFACE

BORING SB010 PS

PAGE 1

* CAPPED INSERTS ARE INDICATED BY A CHECKMARK

CIRCLED SAMPLE # INDICATES SAMPLE TO BE SENT TO LAB FOR ANALYSIS

Source: HNUS, 1993

BORING LOG	Boring/Well No.: VW-1		1 of 1
Installation: FAIRCHILD AFB		Site: PS 2	Project No: [illegible]
Client/Project: AFCEE		Contractor: ENGINEERING - SCIENCE	
Drilling Contractor: ENV WEST		Drillers: RICK McCARRELL & TED MAN	
Drilling Started: 0 9-22-93	Drilling Ended: 0 9-23-93		OSHA Protection Level: D
Drilling Method: AUGER	Sampling Method: SPLIT SPOON		Borehole dia (s): 11"
Geologist: S THOMAS TAYLOR	Borehole Coordinates:		LS Altitude:

DEPTH (feet)	RECOVERY (%)	HEAD SPACE Amount (ppm)	HEAD SPACE Interval (feet)	CHEMICAL SAMPLES No.	CHEMICAL SAMPLES Interval (feet)	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	USCS SOIL CLASSIFICATION	WELL LOG DATA
		[illegible]	[illegible]			0-2' GRAVELLY SAND, GRAY NS-NE, VERY POORLY SORTED, ANGULAR, LOOSE UNCONSOLIDATED DAMP, FUEL ODOR, PROBABLY FILL MATERIAL			
		[illegible]	2.0 2.5			2'-2.5 SAND, DARK GREENISH-GRAY, WELL SORTED, MICACEOUS, DAMP, WELL ROUNDED, LOOSE-UNCONSOLIDATED, FUEL ODOR			
		[illegible]	3.0 3.5			2.5-3.0 SAND AS ABOVE WITH PEBBLY GRAVEL 3.0-6.0 AS ABOVE SAND & GRAVEL, MINOR CLAY			
5		3100 984	6.0-6.5			6.0-8.0 SAND AND GRAVEL, SILTY, MINOR, CLAY, DARK BROWN, POORLY ROUNDED, POORLY SORTED, DAMP FUEL ODOR, UNCONSOLIDATED			
		3600 1051	7.0-7.5	PS-2-VW1-7.5	78-84" 90-96" 96-102"	8.0-9.0 SAND AND SILT, VERY FINE GRAINED SAND, MINOR CLAY, DARK BROWN, WELL ROUNDED, WELL SORTED, DAMP WET, FUEL ODOR, UNCONSOLIDATED BUT COHESIVE			
10									
15									
20									
25									
30									

Source: ES, 1994

BORING LOG | Boring/Well No.: VMP-1

Site: PS-2 | Project No: DE268

Installation: FAIRCHILD AFB

Client/Project: AFCEE | Contractor: ENGINEERING - SCIENCE

Drilling Contractor: ENV WEST | Drillers: RICK McCORKLE & TED MAY

OSHA Protection Level: D

Drilling Started: () 9-23-93 | Drilling Ended: () 9-23-93

Borehole dia (s): 8"

Drilling Method: AUGER | Sampling Method: SPLIT SPOON

LS Altitude:

Geologist: S. THOMAS TAYLOR | Borehole Coordinates:

DEPTH (feet)	RECOVERY (%)	HEAD SPACE		CHEMICAL SAMPLES		LITHOLOGIC DESCRIPTION	GRAPHIC LOG	USCS SOIL CLASSIFICATION	WELL LOG DATA
		Amount (ppm)	Interval (feet)	No.	Interval (feet)				
		2600 1062	0-6"			0.0-2.0 GRAVELLY SAND, GRAY (N5-N6), VERY POORLY SORTED, ANGULAR, LOOSE-UNCONSOLIDATED, DAMP, FUEL ODOR, PROBABLY FILL MATERIAL		18 40 50 49	
		8200 1453	24-27"			2.0-2.5 SILT WITH VERY FINE-GRAINED SAND, BROWN-ISH-BLACK, WELL SORTED, DAMP, FUEL ODOR, FIRM		19 10	← 35" BOULDER REFUSAL
5		6200 1409	48-54"	PS2-VMP1-4	53-59 54-60 60-66	2.5-3.3 SAND, GREENISH GRAY, FINE-GRAINED, MINOR SILT, MOD. SORTING, MOD. ROUNDED, DAMP, FUEL ODOR		8 13 19 19	
		3400 1026	72-78"			3.3-5.5 SILTY SAND, SAND IS VERY FINE GRAINED, DARK BROWN, POORLY SORTED, POORLY ROUNDED, OCCASIONAL PEBBLES, DAMP, FUEL ODOR, UN-CONSOLIDATED.		7 26 40 55	
		9200 1304	96-102			5.5-7.0 AS ABOVE BUT AVERAGE GRAIN SIZE INCREASING DOWNWARD		4 14 30 50	
10						7.0-8.0 NOT RECOVERED			
						8.0-8.6 SILT AND CLAY, DARK BROWN, POSSIBLY ORGANIC RICH, WET, FIRM, FUEL ODOR			
						8.6-9.0 SAND, GRAY, COARSE GRAINED, WELL SORTED, POORLY ROUNDED, WET, FUEL ODOR, UNCONSOLIDATED			
15									
20									
25									
30									

Source: ES, 1994

IORING LOG	Boring/Well No.: VMP-2		
		Site: PS-2	Project No: DE 268
tallation: FAIRCHILD AFB			
int/Project: AFCEE	Contractor: ENGINEERING - SCIENCE		
lling Contractor: ENV. WEST	Drillers: RICK McCORKLE & TED MAY		
lling Started: () 9-24-93	Drilling Ended: () 9-24-93		OSHA Protection Level: D
lling Method: AUGER	Sampling Method: SPLIT SPOONS		Borehole dia (s): 8"
			LS Altitude:
ologist: S. THOMAS TAYLOR	Borehole Coordinates:		

(feet)	RECOVERY (%)	HEAD SPACE		CHEMICAL SAMPLES		LITHOLOGIC DESCRIPTION	GRAPHIC LOG	USCS SOIL CLASSIFICATION	WELL LOG DATA
		Amount (ppm)	Interval (feet)	No.	Interval (feet)			Bl...	
		2700 689	0-0.5			0-2: 0-6" GRAVEL, GRAY, POORLY SORTED, ANGULAR, DAMP FUEL ODOR, UNCONSOLIDATED. 6-24" SAND, GRAY, MOD SORTING, MOD. RNDED.; DAMP, FUEL ODOR UNCONSOLIDATED. WITH PERCENTAGE OF SILT INCREASING DOWNWARD		24 12 16 40	
		10,000+ 924	2.0-2.5	—	—	2-4 SAND, SILTY, DARK BROWN, FINEGRAINED, MOD. ROUNDED MOD. SORTING, DAMP, FUEL ODOR, UNCONSOLIDATED SOME GRAVEL IN BOTTOM SIX INCHES (42-48").		[illegible] 40	
5		8300 1155	4.0-4.5	PS2-VMP2-4	4.5-6.0	4-6 AS ABOVE WITH GRAINSIZE DECREASING DOWNWARD, FUEL ODOR		[illegible]	
		2900 981	6.0-6.1			6-7'2" VERY FINE GRAINED SAND AND SILT, ROUNDED MODERATE TO GOOD SORTING, DAMP, UNCONSOLIDATED FUEL ODOR. OCCASIONAL PEBBLES AND COBBLES		15 37 SC [illegible] 2"	
						T.D. 7'2"			
10									
15									
20									
25									
30									

Source: ES, 1994

BORING LOG

Boring/Well No.: VMP-3

Installation: FAIRCHILD AFB | Site: PS-2 | Project No: DC268

Client/Project: AFCEE | Contractor: ENGINEERING-SCIENCE

Drilling Contractor: ENV. WEST | Drillers: RICK McCORCLE & TED MAY

Drilling Started: 0 9-28-93 | Drilling Ended: 0 9-28-93 | OSHA Protection Level:

Drilling Method: AUGER | Sampling Method: SPLIT SPOON | Borehole dia (s): 8"

Geologist: S. THOMAS TAYLOR | Borehole Coordinates: | LS Altitude:

DEPTH (feet)	RECOVERY (%)	HEAD SPACE Amount (ppm)	HEAD SPACE Interval (feet)	CHEMICAL SAMPLES No.	CHEMICAL SAMPLES Interval (feet)	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	USCS SOIL CLASSIFICATION	WELL LOG DATA
		<100	0-0.5			0-1' SAND, GRAY-GREEN COARSE GRAINED, MINOR SILT, POORLY ROUNDED, POORLY SORTED, DAMP, FUEL ODOR, UNCONSOLIDATED PROBABLY FILL, GRAVEL ALSO IN SAMPLE		17 50	
		6200	2.0-2.5			1-2' NO RECOVERY		21 22 25 30	
		1000+	3.0-3.5			2-4 SAND AND SILT, COARSE GRAINED, VERY POORLY SORTED, OCCASIONAL PEBBLES, POORLY ROUNDED, DAMP, FUEL ODOR, UNCONSOLIDATED		7 15 26 35	
		1000+	4.5-5.0						
		2900	5.5-6.0			4-6 SAND AND SILT AS ABOVE WITH 6" THICK LENSE OF CLEAN SAND AT 5'		5 8 8 20	
		3700	6.5-7.0						
		1150	7.5-8.0			6-8 SILTY SAND AS ABOVE WITH SILT INCREASING DOWNWARD, FUEL ODOR (SLIGHTLY LESS STRONG THAN ABOVE).			

Source: ES, 1994

WELL DRILLING LOG

PROJECT	FAFB 41584-504-07	WELL ID.	MW-229 PAGE 1 OF 2
DATE(S) DRILLED	11-14-94	RIG TYPE	INGERSOL RAND A300/140# CORE DR.
GEOLOGIST/ENGINEER	MITCH HALL	LOCATION	PS-2
GEOLOGIST/ENGINEER	JIM BUSH	WATER LEVEL	MOIST AT 5.5', SATURATED AT 8'
DRILLING SUBCONTRACTOR	ENVIRONMENTAL WEST	TOTAL DEPTH OF HOLE	16.5'

DEPTH (ft) BGS AS DRILLED	RECOVERY (%)	BLOWS/6in. 140# HAMMER	BOREHOLE METER READING	SAMPLE ID.	SAMPLES	GENERAL LITHOLOGY	MATERIALS DESCRIPTION	WELL DIAGRAM
0							SW – AUGERED. MEDIUM SAND. DARK BROWN FILL.	
1								CON-CRETE; PVC CASING
	100%			PS02229S01				
2								
3							3 ppm IN BOTTOM HALF. SILTY, SLIGHTLY CLAYEY MEDIUM SAND. MEDIUM BROWN.	BENT-ONITE; RISER
4								
5		11						SAND FILTER PACK
6		15					BOTTOM 2-4" WET IN CORE BARREL. BOTTOM 4" COARSE BASALTIC GREEN TO GRAY. GRANULAR SAND ~30% GRANULES.	PVC SCREEN
		22	2-3 ppm				SW – UPPER 6" MIXED TWO PREVIOUS LITHOLOGIES (SLOUGH?). MIXED BASALTIC GRAVEL AND SAND. ~30% GRANULAR, ~30% COARSE SAND, ~30% PEBBLES. BOTTOM 1" VERY CLEAN, FINE SAND TO SILT. WET.	
7		16						
		23						
8	▽	21	3 ppm					
			Notable petroleum odor, 18 ppm	PS02229S02			ALL WET (8' TO 9.5'). BASALTIC GRAVEL CONTINUED. SAMPLE = 24 ppm.	
9		15	Notable petroleum odor, 20 ppm					
		14					CL – STIFF CLAYEY SILT FROM 8'10" TO 11'2". SCATTERED SMALL GRAINS OF ROUNDED SAND (TRACE). LIGHT REDDISH-BROWN OVER ALL COLOR.	
10		7						
		11					STA. CLAY BECOMING REDUCED. MOTTLED WITH PATCHES OF GRAY IN LOWER PORTION FROM ABOUT 10' DOWN. VERY UNIFORM CONSISTENCY.	
11		25	83 ppm					
		10					SW – CORE = 0 ppm. UNIFORM VERY COARSE TO GRANULE SAND. NO ODOR., DOMINATELY BASALTIC.	
12		27						
		30						
13		3					UNIFORM VERY COARSE SAND. VARIEGATED. EMPHASIZES BASALTIC COMPOSITION, WITH YELLOW, RED AND ORANGE GRAINS.	
		20						
14		35	3 ppm				STOPPED SPLIT SPOON. AUGERED TO TOTAL DEPTH. SAND SIMILAR TO ABOVE OBSERVED ON AUGER PLUG TO 16'.	
15								

Source: ICF, 1995

DRAWING FILE: MW-229.dwg

WELL DRILLING LOG

PROJECT	FAFB 41534-504-07	WELL ID.	MW-229 PAGE 2 OF 2
DATE(S) DRILLED	11-14-94	RIG TYPE	INGERSOL RAND A300/140# C.D.
GEOLOGIST/ENGINEER	MITCH HALL	LOCATION	PS-2
GEOLOGIST/ENGINEER	JIM BUSH	WATER LEVEL	MOIST AT 5.5', SATURATED AT 8'
DRILLING SUBCONTRACTOR	ENVIRONMENTAL WEST	TOTAL DEPTH OF HOLE	16.5'

DEPTH (ft) BGS AS DRILLED	RECOVERY (%)	BLOWS/6in. 140# HAMMER	BORHOLE METER READING	SAMPLE ID.	SAMPLES	GENERAL LITHOLOGY	MATERIALS DESCRIPTION	WELL DIAGRAM
16	100						SOME HEAVING SAND AT BOTTOM. (~1.5'-2' FROM BOTTOM) TOTAL DEPTH = 16.5' BELOW GROUND SURFACE AS DRILLED. (6 BAGS SAND, 3 BAGS HOLE PLUG USED)	SAND FILTER PACK SUMP CAP
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

Source: ICF, 1995

DRAWING FILE: MW-229B.dwg

APPENDIX B - 1b

GROUNDWATER BTEX AND TPH RESULTS

Table 4-19. Historical Analytical Results for Groundwater - Site OU-1 Total Petroleum Hydrocarbons, and Volatile Organic Compounds

Fairchild AFB
Historical Analytical Results, Site OU-1
Groundwater Samples
Total Petroleum Hydrocarbons (ug/L), Common Anions (ug/L), Volatile Organic Compounds (ug/L)

WELL NO.	SAMPLE NUMBER	AGENCY	SAMPLE DATE mm/dd/yy	TOTAL PETROLEUM HYDROCARBONS QUAL	1,2-DICHLOROBENZENE QUAL	1,3-DICHLOROBENZENE QUAL	1,4-DICHLOROBENZENE QUAL	BENZENE 71-43-2 QUAL	ETHYL BENZENE 100-41-4 QUAL	TOLUENE 108-88-3 QUAL
MW-30	GN-86-0202	DOD	11/18/86	2.7 J	34.2	0.4 U	619	4.8	28.7	1.5
MW-30	GN-87-0302	DOD	11/19/87	0.5 U	0.5 U	0.5 U	0.5 U	8.5	0.5 U	1.6
MW-30	PS8-GW-MW30-003	DOD	04/18/89	4.9 J	5 U	5 U	5 U	17	5 U	5 UR
MW-30	PS8-GW-MW30-004D	DOD	04/18/89	1.3 J	25 U	25 U	25 U	41	440	33 R
MW-30	PS8-GW-MW30-005	DOD	07/26/89	1.8 J	5 U	5 U	5 U	26	300	32 R
MW-31	GN-86-0204	DOD	11/18/86	5.9 J	48	130	700	198	348	46.1
MW-31	GN-87-0304	DOD	11/20/87	0.5 U	10 U	10 U	410	27	10 U	10 U
MW-31	GN-87-0354D	DOD	11/20/87	0.5 U	13 U	13 U	420	65	13 U	13 U
MW-31	PS8-GW-MW31-003	DOD	04/18/89	0.3 J	25 U	25 U	25 U	25 U	1300	0.5 UR
MW-31	PS8-GW-MW31-004	DOD	07/25/89	5.4 J	25 U	25 U	25 U	25 U	590	140 R
MW-31	PS8-GW-MW31-005D	DOD	07/25/89	4.9 J	25 U	25 U	25 U	25 U	530	130 R
MW-32	GN-86-0203	DOD	11/18/86	1 U	0.4 U	0.4 U	0.3 U	0.2 U	0.2 U	0.2 U
MW-32	PS8-GW-MW32-002	DOD	04/18/89	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.6 R
MW-55	PS2-GW-MW55-001	DOD	04/25/89	0.8 J	5 U	5 U	5 U	15	19	1.6 JR
MW-55	PS2-GW-MW55-002D	DOD	04/25/89	0.6 J	5 U	5 U	5 U	14	21	6 R
MW-55	PS2-GW-MW55-003	DOD	07/25/89	0.6 J	0.5 U	0.5 U	0.5 U	29	35	0.6 JR
MW-56	PS2-GW-MW56-001	DOD	04/25/89	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	3.6 JR
MW-56	PS2-GW-MW56-002	DOD	07/25/89	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	12 R
MW-56	PS2-GW-MW56-003D	DOD	07/25/89	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 UR
MW-66	PS8-GW-MW66-001	DOD	04/26/89	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	8.2 R
MW-66	PS8-GW-MW66-002	DOD	07/25/89	0.2 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	13 R
MW-67	PS8-GW-MW67-001	DOD	04/25/89	0.5 J	5 U	5 U	5 U	5 U	430	27 R
MW-67	PS8-GW-MW67-002	DOD	07/26/89	3.7 J	25 U	25 U	25 U	25 U	410	25 R
MW-68	PS8-GW-MW68-001	DOD	04/25/89	6.3 J	5 U	5 U	5 U	5 U	320	5 UR
MW-68	PS8-GW-MW68-002	DOD	07/25/89	1.8 J	5 U	5 U	5 U	5 U	150	5 UR

Source: SAIC, 1990

Table 4-19. [redacted] Historical [redacted] Analytical Resul[redacted] Gro[redacted]ter - [redacted] OU-1 [redacted] Pet[redacted]
Hydrocarbons, and Volatile Organic Compounds
(Continued)

Fairchild AFB
Historical Analytical Results, Site OU-1
Groundwater Samples
Total Petroleum Hydrocarbons (ug/L), Common Anions (ug/L), Volatile Organic Compounds (ug/L)

WELL NO.	SAMPLE NUMBER	AGENCY	SAMPLE DATE mm/dd/yy	XYLENES (TOTAL) 1330-20-7	QUAL	P-XYLENE	QUAL	M-XYLENE	QUAL	O-XYLENE	QUAL
MW-30	GN-86-0202	DOD	11/18/86			36.3		49.8		78.5	
MW-30	GN-87-0302	DOD	11/19/87	260							
MW-30	PS8-GW-MW30-003	DOD	04/18/89	530							
MW-30	PS8-GW-MW30-004D	DOD	04/18/89	1100							
MW-30	PS8-GW-MW30-005	DOD	07/26/89	820							
MW-31	GN-86-0204	DOD	11/18/86			0.3	U	3150		1180	
MW-31	GN-87-0304	DOD	11/20/87	1800							
MW-31	GN-87-0354D	DOD	11/20/87	2300							
MW-31	PS8-GW-MW31-003	DOD	04/18/89	4400							
MW-31	PS8-GW-MW31-004	DOD	07/25/89	3400							
MW-31	PS8-GW-MW31-005D	DOD	07/25/89	3000							
MW-32	GN-86-0203	DOD	11/18/86			0.3	U	0.3	U	0.3	U
MW-32	PS8-GW-MW32-002	DOD	04/18/89	1	U						
MW-55	PS2-GW-MW55-001	DOD	04/25/89	72							
MW-55	PS2-GW-MW55-002D	DOD	04/25/89	72							
MW-55	PS2-GW-MW55-003	DOD	07/25/89	150							
MW-56	PS2-GW-MW56-001	DOD	04/25/89	1	U						
MW-56	PS2-GW-MW56-002	DOD	07/25/89	1	U						
MW-56	PS2-GW-MW56-003D	DOD	07/25/89	1	U						
MW-66	PS8-GW-MW66-001	DOD	04/26/89	1	U						
MW-66	PS8-GW-MW66-002	DOD	07/25/89	1	U						
MW-67	PS8-GW-MW67-001	DOD	04/25/89	1900							
MW-67	PS8-GW-MW67-002	DOD	07/26/89	1600							
MW-68	PS8-GW-MW68-001	DOD	04/25/89	960							
MW-68	PS8-GW-MW68-002	DOD	07/25/89	470							

Source: SAIC, 1990

TABLE K-3.6

TOTAL PETROLEUM HYDROCARBON AND VOLATILE ORGANIC CHEMICAL MONITORING DATA
SITE PS-2
FAIRCHILD AFB, WASHINGTON

Monitoring Well	Sampling Round						
	R3	R4	R6	R7	R8	R9	R11
UPGRADIENT WELL							
56	NCD	NCD	NCD	NCD			NCD
DOWNGRADIENT ALLUVIAL MONITORING WELLS							
55	TPH = 6.8 mg/L B = 15 EB = 21 X = 72	TPH = 0.6 mg/L B = 29 EB = 35 X = 150	TPH = 2 mg/L B = 12 EB = 12	B = 53 EB = 180 X = 270			B = 10 EB = 13 X = 25
105					NCD	NCD	
106					NCD	NCD	EB = 5 X = 12
109					TPH = 16 mg/L B = 150 EB = 530 X = 1,200	TPH = 6.8 mg/L B = 34 X = 290	TPH = 4.4 B = 40 EB = 190 X = 420
110					CB = 4	CB = 2	CB = 18
176							TPH = 110 B = 2,600 EB = 1,200 X = 5,000
177							TPH = 27 B = 240 EB = 520 X = 2,200
DOWNGRADIENT BASALT A MONITORING WELLS							
178							B = 7 EB = 11 X = 40
180							NCD

NCD No VOCs detected

B Benzene (µg/L)
CB Chlorobenzene (µg/L)
EB Ethylbenzene (µg/L)
X Xylenes (µg/L)
TPH Total Petroleum Hydrocarbons (mg/L)

Source: HNUS, 1993

TABLE 3-6

QUARTERLY OVERBURDEN AQUIFER, GROUNDWATER SAMPLE RESULTS ($\mu g/L$)
AUGUST 1994
FLOATING FREE-PRODUCT RECOVERY TREATABILITY STUDY
ON-BASE PRIORITY ONE OPERABLE UNIT, FLIGHTLINE OPERABLE UNIT, SITE PS-2
FAIRCHILD AIR FORCE BASE, WASHINGTON

Analyte	MW-55	MW-110	MW-176	MW-177	MW-177A	MW-177B*
Benzene	20	5 U	1200	120 U	5 U	5 U
Toluene	5 U	5 U	2500	120 U	5 U	5 U
Ethylbenzene	31	5 U	580	590	5 U	5 U
m/p Xylenes	8	5 U	2000	2400	5 U	5 U
o-Xylene	5 U	5 U	2500	120 U	5 U	5 U

Analyte	MW-222	MW-224	MW-228	MW-228A	MW-228B	MW-228C**
Benzene	44	11	220	410	67	66
Toluene	5 U	5 U	120 U	250 U	5 U	5 U
Ethylbenzene	14	94	240	430	67	68
m/p Xylenes	9	38	970	2000	190	180
o-Xylene	5 U	5 U	120 U	250 U	7	7

* Duplicate sample from MW-177A.
** Duplicate sample from MW-228B.

Source: HNUS, 1994

TABLE 3-5

AUGUST 1994 QUARTERLY GROUNDWATER SAMPLING RESULTS ($\mu g/L$)
FLOATING FREE-PRODUCT RECOVERY TREATABILITY STUDY
ON-BASE PRIORITY ONE OPERABLE UNIT, FLIGHTLINE OPERABLE UNIT
FAIRCHILD AIR FORCE BASE, WASHINGTON

	Gasoline Petroleum Hydrocarbons	Diesel Petroleum Hydrocarbons
MW-55	890 J	200
MW-110	260 J	100 U
MW-176	25,000 J	100,000
MW-177	11,000 J	7,800 J
MW-177A	360 J	100 U
MW-177B*	550 J	100 U
MW-222	6905	1000
MW-224	1,400 J	830 J
MW-228	25,000 J	100,000 J
MW-228A	490,000 J	190,000 J
MW-228B	1,600 J	770
MW-228C**	2,100 J	710

* Duplicate sample from MW-177A.
** Duplicate sample from MW-228B.

Source: HNUS, 1994

TABLE 3-6

QUARTERLY OVERBURDEN AQUIFER, GROUNDWATER SAMPLE RESULTS ($\mu g/L$)
NOVEMBER 1994
FLOATING FREE-PRODUCT RECOVERY TREATABILITY STUDY
ON-BASE PRIORITY ONE OPERABLE UNIT, FLIGHTLINE OPERABLE UNIT, SITE PS-2
FAIRCHILD AIR FORCE BASE, WASHINGTON

Analyte	MW-55	MW-109	MW-110	MW-176	MW-177	MW-177A
Benzene	8	12	5 U	2100	100 U	5
Toluene	5 U	5 U	5 U	500 U	100 U	5 U
Ethylbenzene	12	550	5 U	2400	420	5 U
m/p Xylenes	5 UJ	930 J	5 U	11,000	1900	5 J
o-Xylene	5 U	5 U	5 U	500 U	100 U	5 U
Chlorobenzene	5 U	5 U	44	500 U	100 U	5 U

Analyte	MW-222	MW-224	MW-228	MW-228A	MW-228B
Benzene	79	52	490	2000	28 J
Toluene	5 U	5 U	83 U	250 U	5 U
Ethylbenzene	26	140	420	1400	22 J
m/p Xylenes	5 U	180	2000	5400	77 J
o-Xylene	5 U	5 U	83 U	250 U	5 U
Chlorobenzene	5 U	5 U	83 U	250 U	5 U

Source: HNUS, 1995b

TABLE 3-5

NOVEMBER 1994 QUARTERLY GROUNDWATER SAMPLING RESULTS ($\mu g/L$)
FLOATING FREE-PRODUCT RECOVERY TREATABILITY STUDY
ON-BASE PRIORITY ONE OPERABLE UNIT, FLIGHTLINE OPERABLE UNIT
FAIRCHILD AIR FORCE BASE, WASHINGTON

	Gasoline Petroleum Hydrocarbons	Diesel Petroleum Hydrocarbons
MW-55	120	250 U
MW-109	4800	2,100
MW-110	200	250 U
MW-176	22,000	75,000
MW-177	11,000	13,000 J
MW-177A	270	250 U
MW-222	8500	380
MW-224	1900	1100
MW-228	31,000	54,000
MW-228A	45,000	110,000
MW-228B	1300	400

Source: HNUS, 1995b

TABLE 4-2. SUMMARY OF PURGEABLE AROMATIC VOLATILE ORGANICS (SW5030/SW8020) LABORATORY ANALYSIS OF SAMPLES COLLECTED AT PS-2 IN NOVEMBER 1994

PARAMETERS	PRACTICAL QUANTITATION LIMIT	ENVIRONMENTAL SAMPLE								
		55		56		105	109		110	
		PS02055W22[1]	PS02055W22[2]	PS02056W23	PS02357W32[3]	PS02105W24	PS02109W25	PS02109W25[2]	PS02110W26	PS02110W26[2]
		108467-0004-SA	108467-0004-SA	108467-0005-SA	108467-0010-SA	108467-0006-SA	108467-0007-SA	108467-0007-SA	108467-0008-SA	108467-0008-SA
LABORATORY ANALYSIS[4]										
Benzene	0.50 µg/L	11.0 µg/L	10 µg/L	0.50 U µg/L	0.50 U µg/L	0.50 µg/L	10 U µg/L	10 U µg/L	2.7 µg/L	1.8 µg/L
Toluene	1.0 µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	20 U µg/L	20 U µg/L	2.5 µg/L	1.3 µg/L
Ethylbenzene	1.0 µg/L	18 µg/L	18 µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	530 µg/L	380 µg/L	1.0 U µg/L	1.0 U µg/L
Xylenes, Total	1.0 µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	780 µg/L	670 µg/L	26 µg/L	22.0 µg/L
Surrogate										
Bromofluorobenzene	29-137%	86%	86%	101%	106%	100%	99%	90%	97%	91%
Diesel Fuel #2	0.50 mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA
Jet Fuel	0.50 mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA
Unknown Hydrocarbon	0.50 mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA
Surrogate										
o-Terphenyl	75-125%	NA	NA	NA	NA	NA	NA	NA	NA	NA
FIELD ANALYSIS[5]										
Conductivity	0-50,000 umhos/cm	550 umhos/cm	550 umhos/cm	480 umhos/cm	480 umhos/cm	800 umhos/cm	550 umhos/cm	550 umhos/cm	850 umhos/cm	850 umhos/cm
pH	1-14	6.88	6.88	6.55	6.55	6.87	6.69	6.69	6.85	6.85
Temperature	0-100°C	11°C	11°C	13°C	13°C	8°C	11°C	11°C	10°C	10°C
Turbidity	0-1,000 NTU	287 NTU	287 NTU	762 NTU	762 NTU	404 NTU	284 NTU	284 NTU	255 NTU	255 NTU

Source: ICF, 1995

LE 4-2. SUMMARY OF PURGEABLE AROMATIC VOLATILE ORGANICS (SW5030/SW8020) LABORATORY ANALYSIS OF SAMPLES COLLECTED AT PS-2 IN NOVEMBER 1994 (Continued)

PARAMETERS	PRACTICAL QUANTITATION LIMIT	ENVIRONMENTAL SAMPLE							
		178	179	180	229	170	230		
		PS02178W27	PS02179W28	PS02180W29	PS02229W30	PS02229W30[2]	PS02230W31	PS02230W31[2]	PS02531W32[6]
		108781-0001-SA	108781-0002-SA	108467-0009-SA	108781-0003-SA	108781-0003-SA	108838-0002-SA	108838-0002-SA	108838-0003-SA
LABORATORY ANALYSIS									
Benzene	0.50 µg/L	1.0 U µg/L	1.0 U µg/L	0.50 U µg/L	3.2 µg/L	1.6 µg/L	0.50 U µg/L	0.50 U µg/L	NA
Toluene	1.0 µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	3.9 µg/L	3.2 µg/L	1.0 U µg/L	1.0 U µg/L	NA
Ethylbenzene	1.0 µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	21 µg/L	14 µg/L	2.7 µg/L	3.7 µg/L	NA
Xylenes, Total	1.0 µg/L	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	7.4 µg/L	8.0 µg/L	1.0 U µg/L	1.0 U µg/L	NA
Surrogate Bromofluorobenzene	29-137%	92%	100%	100%	116%	102%	130%	106%	NA
Diesel Fuel #2	0.50 mg/L	NA	NA	NA	0.50 U mg/L	NA	0.50 U mg/L	NA	0.50 U mg/L
Jet Fuel	0.50 mg/L	NA	NA	NA	0.50 U mg/L	NA	0.50 U mg/L	NA	0.50 U mg/L
Unknown Hydrocarbon	0.50 mg/L	NA	NA	NA	0.87 mg/L y	NA	0.50 mg/L y	NA	0.53 mg/L y
Surrogate o-Terphenyl	75-125%	NA	NA	NA	86%	NA	100%	NA	116%
FIELD ANALYSIS									
Conductivity	0-50,000 umhos/cm	415 umhos/cm	180 umhos/cm	180 umhos/cm	625 umhos/cm	625 umhos/cm	650 umhos/cm	650 umhos/cm	650 umhos/cm
pH	1-14	6.79	7.91	7.67	8.22	8.22	7.02	7.02	7.02
Temperature	0-100°C	11°C	10°C	14°C	11°C	11°C	11.5°C	11.5°C	11.5°C
Turbidity	0-1,000 NTU[4]	105 NTU	963 NTU	142 NTU	87.2 NTU	87.2 NTU	171 NTU	171 NTU	171 NTU

Source: ICF, 1995

Table A-1
Analytical Results

Base: Fairchild AFB
Site: PS-2
Method Extraction: WTPH-D
Method Analytical: WTPH-D
Matrix: groundwater
Units: µg/L
Data Validation SDG: 950433

Contract No.: F41624-94-D-8052
Delivery Order: 12

			Environmental Samples			Field blanks			Method blanks
Parameters	PQL	Action Level*	Field ID Lab ID Column 1	Field ID Lab ID Column 2	Field ID Lab ID Primary	Trip Field ID Lab ID	Equip Field ID Lab ID	Ambient Field ID Lab ID	Field ID Lab ID
TPH-Diesel	500	1000			0495PS2MW109 9504181 3900				
TPH-Diesel	500	1000			0495PS2MW109A 9504182 5300				
TPH-Diesel	500	1000			0495PS2MW179 9504183 270				
TPH-Diesel	500	1000			0495PS2MW178 9504184 270				
TPH-Diesel	500	1000			0495PS2MW110 9504189 720				

Surrogate:Octacosane, Limits 50-150

Source: ES&T AND MWA, 1995

* Numeric action level values from ROD
** Action level not specified in ROD

Table A
Analytical Results

Base: Fairchild AFB
Site: PS-2
Method Extraction: not applicable
Method Analytical: 8020
Matrix: groundwater
Units: ug/L
Data Validation SDG: 950433

Contract No.: F41624-94-D-8052
Delivery Order: 12

Parameters	PQL	Action Level*	Environmental Samples: Field ID Lab ID Column 1	Environmental Samples: Field ID Lab ID Column 2	Environmental Samples: Field ID Lab ID Primary	Field blanks: Trip Field ID Lab ID	Field blanks: Equip Field ID Lab ID	Field blanks: Ambient Field ID Lab ID	Method blanks: Field ID Lab ID
					0495PS2MW55				
					9504188F				
Benzene	1	5			16				
Ethylbenzene	1	**			19				
Meta & Para Xylenes	1	**			1.7				
					0495PS2MW110				
					9504189F				
Benzene	1	5			2.2				
Chlorobenzene	1	**			2.1				
Ethylbenzene	1	**			3.0				
Meta & Para Xylenes	1	**			1.0				

Surrogate: bromofluorobenzene, Limits 69-126

Source: ES&T AND MWA, 1995

* Numeric action level values from ROD
** Action level not specified in ROD

Table A-1
Analytical Results

Base: Fairchild AFB
Site: PS-2
Method Extraction: not applicable
Method Analytical: 8020
Matrix: groundwater
Units: ug/L
Data Validation SDG: 950433

Contract No.: F41624-94-D-8052
Delivery Order: 12

			Environmental Samples			Field blanks			Method blanks
Parameters	PQL	Action Level*	Field ID Lab ID Column 1	Field ID Lab ID Column 2	Field ID Lab ID Primary	Trip Field ID Lab ID	Equip Field ID Lab ID	Ambient Field ID Lab ID	Field ID Lab ID
					0495PS2MW109A				
					9504182				
Benzene	1	5			21				
Toluene	1	**			1.2				
Ethylbenzene	1	**			120				
Meta & Para Xylenes	1	**			150				
Ortho Xylenes	1	**			2.6				
1,3-Dichlorobenzene	1	**			17				
1,4-Dichlorobenzene	1	**			14				
1,2-Dichlorobenzene	1	**			37				
					0495PS2MW178				
					9504184				
Meta & Para Xylenes	1	**			1.3				
					0495PS2MW180				
					9504186				
Meta & Para Xylenes	1	**			1.7				

Source: ES&T AND MWA, 1995

* Numeric action level values from ROD
** Action level not specified in ROD

Table A-1
Analytical Results

Base: Fairchild AFB
Site: PS-2
Method Extraction: not applicable
Method Analytical: 8020
Matrix: groundwater
Units: ug/L
Data Validation SDG: 950433

Contract No.: F41624-94-D-8052
Delivery Order: 12

Parameters	PQL	Action Level*	Environmental Samples Field ID Lab ID Column 1	Environmental Samples Field ID Lab ID Column 2	Environmental Samples Field ID Lab ID Primary	Field blanks Trip Field ID Lab ID	Field blanks Equip Field ID Lab ID	Field blanks Ambient Field ID Lab ID	Method blanks Field ID Lab ID
						0495PS2FTB1			
						9504187F			
Toluene	1	**				5.2			
					0495PS2MW109				
					9504181				
Benzene	1	5			23				
Toluene	1	**			2.2				
Ethylbenzene	1	**			160				
Meta & Para Xylenes	1	**			170				
Ortho Xylenes	1	**			54				
1,3-Dichlorobenzene	1	**			76				
1,4-Dichlorobenzene	1	**			38				
1,2-Dichlorobenzene	1	**			33				

Source: ES&T AND MWA, 1995

* Numeric action level values from ROD
** Action level not specified in ROD

APPENDIX B - 1c

LNAPL MEASUREMENT RESULTS

R11 sampling event and during the March 1992 round of water level measurements. The depths of the floating products were measured as follows:

Well Number and Date	Floating Product Thickness(1) (Feet)	Depth to Product(2) (Feet from ground surface)
MW176 01/09/92	0.17	8.57
MW176 04/02/92	0.18	8.68
MW177 01/09/92	0.55	7.40
MW177 04/02/92	1.44	7.55

(1) Product thickness measured with clear bailer.
(2) Depth to product calculated by measuring depth to H_2O with an M-Scope and subtracting product thickness.

Source: HNUS, 1993

TABLE 3-1 (Continued)
OVERBURDEN AQUIFER AND FLOATING FREE-PRODUCT ELEVATIONS AND RECOVERY
FLOATING FREE-PRODUCT RECOVERY TREATABILITY STUDY
ON-BASE PRIORITY ONE OPERABLE UNIT, FLIGHTLINE OPERABLE UNIT, SITE PS-2
FAIRCHILD AIR FORCE BASE, WASHINGTON

Monitoring Well	Water Level (feet above mean sea level)	Floating Free-Product Level (feet above mean sea level)	Floating Free Product Recovered
DECEMBER 27, 1994			
MW-55	2432.64	None observed.	No recovery attempted.
MW-56	2434.41	None observed.	No recovery attempted.
MW-105	No elevation data.	None observed.	No recovery attempted.
MW-106	No elevation data.	None observed.	No recovery attempted.
MW-109	2433.72	None observed.	No recovery attempted.
MW-110	2433.64	None observed.	No recovery attempted.
MW-176	2431.51	None observed.	No recovery attempted.
MW-177	2433.98	None observed.	Adsorbent wick replaced.
MW-177A	2434.14	None observed.	No recovery attempted.
MW-178	2434.12	None observed.	No recovery attempted.
MW-179	2413.13	None observed.	No recovery attempted.
MW-180	2428.92	None observed.	No recovery attempted.
MW-222	2430.78	None observed.	No recovery attempted.
MW-223	2431.51	None observed.	No recovery attempted.
MW-224	2431.60	None observed.	No recovery attempted.
MW-228	2431.25	2431.56	2000 ml FFP/water 7700 ml FFP
MW-228A	*	*	No recovery attempted.
MW-228B	2431.51	None observed.	No recovery attempted.

* Billings corporation canister installed in MW-228A.

Source: HNUS, 1995b

APPENDIX B - 1d

SOIL & SOIL GAS BTEX AND TPH RESULTS

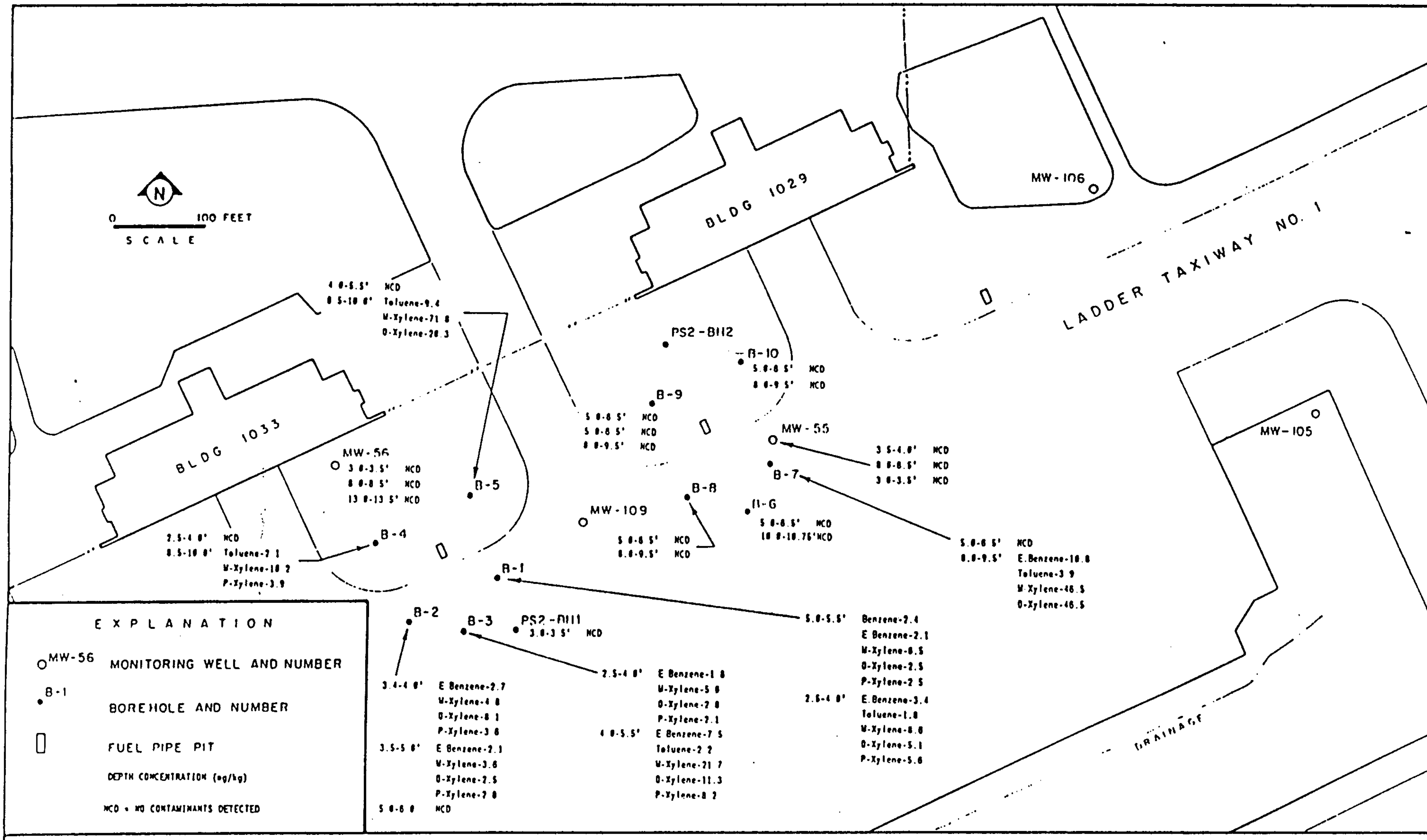


Figure 4-17. Site OU-1 (PS-2) Historical Analytical Results for Soils - VOCs

Source: SAIC, 1990

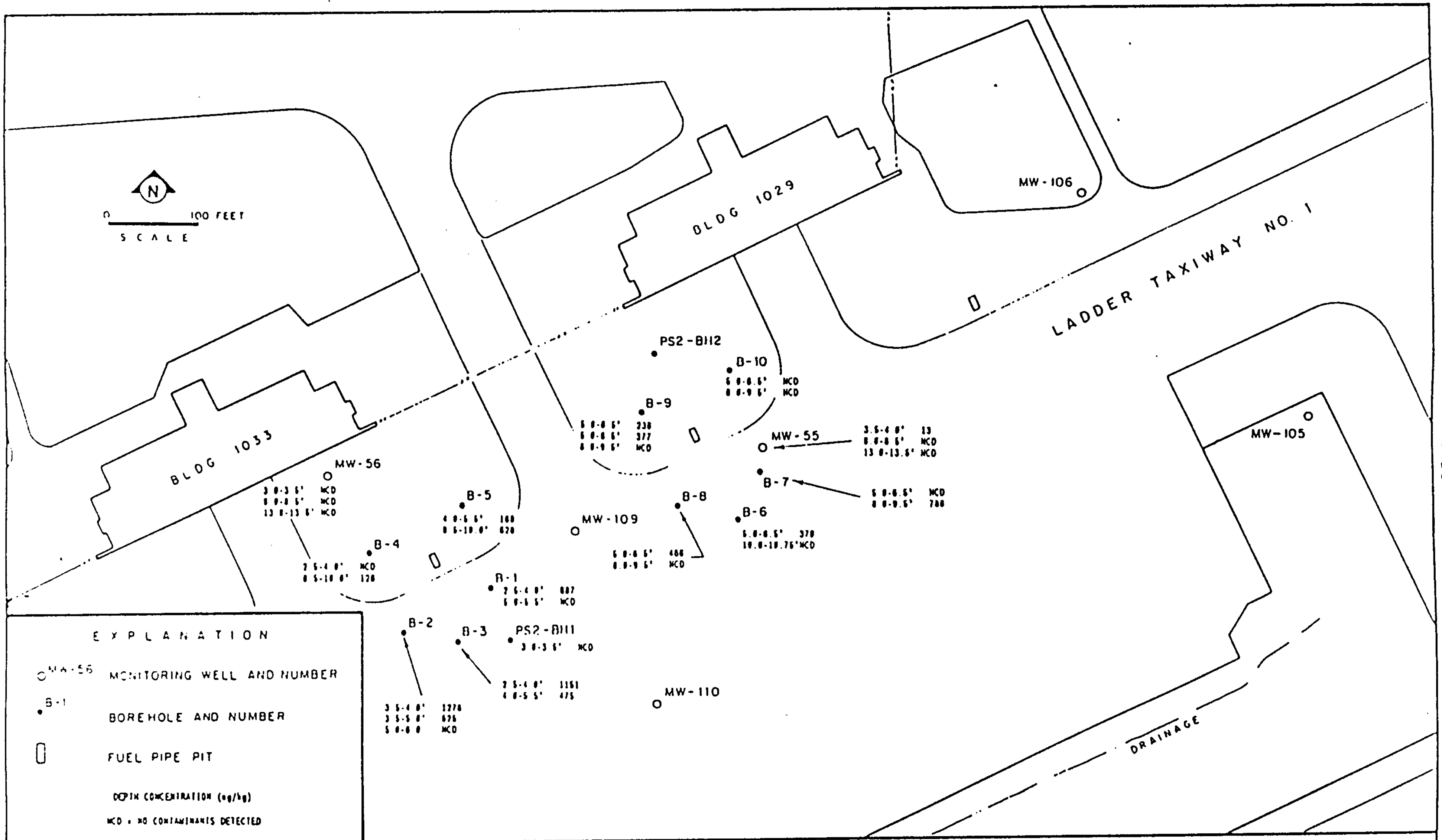


Figure 4-15. Site OU-1 (PS-2) Historical Analytical Results for Soils - TPH

Source: SAIC, 1990

TABLE 4-10

CONTAMINANT OCCURRENCE AND DISTRIBUTION - SOIL BORING SAMPLES
TPH AND BTEX RESULTS (mg/kg)
ROUND 11
SITE PS-2
FAIRCHILD AFB, WASHINGTON

Parameter	Soil Boring									
	1	2	3	4	5	6	7	8	9	10
0- TO 2-FOOT INTERVAL										
Benzene	0.003U(1)(3)		0.003U		0.003U				0.003U	
Toluene	0.003U		0.003U		0.003U				0.003U	
Xylene	0.003U		0.003U		0.003U				0.003U	
Ethylbenzene	0.003U		0.003U		0.003U				0.003U	
TPH	<20(2)				<20				<20	
2- TO 6-FOOT INTERVAL										
Benzene		0.003U	0.004U/ 0.004U		0.004U	**0.006**		0.004U	0.004U	0.003U
Toluene		0.003U	0.004U/ 0.004U		0.004U	0.004U		0.004U	0.004U	0.003U
Xylene		**0.007**	0.004U/ 0.004U		0.004U	0.004U		0.004U	0.004U	0.003U
Ethylbenzene		0.003U	0.004U/ 0.004U		0.004U	**0.005**		0.004U	0.004U	0.003U
TPH		<20	<20/<20		**180**	<20		<20	<20	<20
6- TO 10-FOOT INTERVAL										
Benzene		0.005U				0.460U				
Toluene		0.005U				0.460U				
Xylene		**0.014**				**4.7**				
Ethylbenzene		0.005U				**1.7**				
TPH		<20				<20				

Source: HNUS, 1993

TABLE 4-10
CONTAMINANT OCCURRENCE AND DISTRIBUTION - SOIL BORING SAMPLES
TPH AND BTEX RESULTS (mg/kg)
ROUND 11
SITE PS-2
FAIRCHILD AFB, WASHINGTON
PAGE TWO

Parameter	Soil Boring									
	1	2	3	4	5	6	7	8	9	10
COMPOSITE										
Benzene				0.004U			0.420U			
Toluene				0.004U			0.420U			
Xylene				0.004U			0.420U			
Ethylbenzene				0.004U			0.420U			
TPH				<20			1,200			

(1) U signifies a nondetected result or a detection limit result.
(2) < signifies a nondetected result.
(3)
- 2-Hexanone was also detected in soil sample PS2-SS-001-001 at 0.007 mg/kg.
- Methylene chloride was detected in several subsurface soil samples (PS2-SS-002-002, PS2-SS-003-001,PS2-SS-003-002, PS2SS008-001, PS2SS009-001, and PS2SS009-002) at a concentration range of 0.011 to 0.110 mg/kg.
- Acetone was detected in PS2-SS-006-002 at 1.7 J mg/kg.
- Acetone was detected in PS2SS007-001 at 1.2 J mg/kg.

Source: HNUS, 1993

Table 3.1
INITIAL CONDITIONS
PS-2
Fairchild AFB, Washington

	SOIL GAS				SOIL					
Well No.- depth	O_2 (%)	CO_2 (%)	TVH-jf (ppmv)	TVH (ppmv)	TRPH (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Temp. (°F)
VW1-(5-10)	1.0	7.9	110,000	>10,000	250	0.7	0.5	7.2	47	
VMP1-4	2.5	4.8	78,000	>10,000	280	4.1	ND	21	120	62.8
VMP1-7.5	0.5	4.8		>10,000						63.3
VMP2-4	3.0	0.5		>10,000	980	0.14	ND	0.71	3.8	
VMP2-6.5	0.5	5.2		>10,000						
VMP3-4	2.0	6.5		>10,000						
VMP3-7	0.3	9.7	170,000	>10,000						

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
TVH : Total Volatile Hydrocarbons (THVA field instrument)

ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. O_2/CO_2 measurements by field instrumentation.
2. Soil sample at VW-1 taken at a depth of 7.5 feet bgs.
3. Benzene, Toluene, Ethylbenzene, and Total xylenes by EPA Method 8020.

06/10/94
ps2.xls

Source: ES, 1994

TABLE 2.1
SOIL and SOIL GAS ANALYTICAL RESULTS
PS-2
Fairchild AFB, Washington

ANALYTE	METHOD	UNITS	SAMPLE LOCATION - DEPTH (WELL NUMBER AND FEET BELOW GROUND SURFACE)		
Soil Hydrocarbons:			VW1-7.5	VMP1-4	VMP2-5 [1]
TRPH	EPA 418.1	(mg/kg)	250	280	980
Benzene	SW8020	(mg/kg)	0.7	4.1	0.14
Toluene	SW8020	(mg/kg)	0.5	<0.49	<0.051
Ethylbenzene	SW8020	(mg/kg)	7.2	21	0.71
Xylenes, Total	SW8020	(mg/kg)	47	120	3.8
Soil Inorganics:			VW1-7.5	VMP1-4	VMP2-5 [1]
Iron	SW7380	(mg/kg dry wt.)	23,500	26,100	18,000
Total Alkalinity	SM403	(mg/kg as $CaCO_3$)	580	360	74
pH	SW9045	(units)	7.6	8.1	7
TKN	E351.2	(mg/kg dry wt.)	610	190	130
Total Phosphorus	E365.2	(mg/kg dry wt.)	80	170	92
Soil Physical Parameters:			VW1-7.5	VMP1-4	VMP2-5 [1]
Moisture Content	ASTM D2216	(% by wt.)	15	5.5	9.3
Gravel	ASTM D422	(% by wt.)	4.7	22.9	1.0
Sand	ASTM D422	(% by wt.)	46.6	54.1	64.9
Silt	ASTM D422	(% by wt.)	39.9	14.7	27.0
Clay	ASTM D422	(% by wt.)	8.9	8.2	7.2
Soil Gas Hydrocarbons:			VW1	VMP1-4	VMP3-7
TVH-jf	EPA TO-3	(ppmv)	110,000	78,000	170,000
Benzene	EPA TO-3	(ppmv)	150	160	400
Toluene	EPA TO-3	(ppmv)	<3.7	<2.3	93
Ethylbenzene	EPA TO-3	(ppmv)	24	31	42
Xylenes, Total	EPA TO-3	(ppmv)	130	130	190

NOTES:
TRPH - Total recoverable petroleum hydrocarbons
TVH-jf - Total volatile hydrocarbons as jet fuel
TKN - Total Kjeldahl nitrogen
ppmv - Parts per million by volume
[1] - Sample labelled as VMP2-4, but collected at 5 ft bgs

$CaCO_3$ - Calcium carbonate
mg/kg - milligrams per kilogram
NA - Not Analyzed

06/20/94
ps2.xls

Source: ES, 1994

TABLE 4-3. SUMMARY OF PURGEABLE AROMATIC VOLATILE ORGANICS (SW5030/SW8020) AND PETROLEUM HYDROCARBONS (WTPH-D) LABORATORY ANALYSIS FOR SOIL SAMPLES COLLECTED AT PS-2 WELL BORINGS MW-229 AND MW-230 IN NOVEMBER 1994

PARAMETERS	PRACTICAL QUANTITATION LIMIT	ENVIRONMENTAL SAMPLE				FIELD BLANKS		METHOD BLANKS		
		PS02229S01	PS02229S02	PS02230S03	PS02531S04[1]	PS02229E05[2]	PS02FQCT06[3]	22NOV94-A0	23NOV94-A1	23NOV94-A1X
	SOIL (WATER)	108692-0003-SA	108692-0004-SA	108692-0005-SA	108692-0006-SA	108692-0002-EB	108692-0001-TB	108692	108692	108692
LABORATORY ANALYSIS[4]										
Depth of Sample (feet)	NA	5.5-6.0	8.0-9.0	7.0-8.0	7.0-8.0	NA	NA	NA	NA	NA
Percent Moisture (%)	NA	11.2	13.2	7.9	7.8	NA	NA	NA	NA	NA
Benzene	0.0050 mg/kg (0.50 µg/L)	0.0050 U mg/kg	0.25 U mg/kg	0.0050 U mg/kg	0.0050 U mg/kg	1.0 U µg/L	0.50 U µg/L	0.50 U µg/L	0.0050 U mg/kg	0.25 U mg/kg
Toluene	0.0050 mg/kg (1.0 µg/L)	0.0050 U mg/kg	0.25 U mg/kg	0.0050 U mg/kg	0.0050 U mg/kg	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	0.0050 U mg/kg	0.25 U mg/kg
Ethylbenzene	0.0050 mg/kg (1.0 µg/L)	0.0050 U mg/kg	0.25 U mg/kg	0.0050 U mg/kg	0.0050 U mg/kg	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	0.0050 U mg/kg	0.25 U mg/kg
Xylenes, Total	0.0050 mg/kg (1.0 µg/L)	0.0050 U mg/kg	0.25 U mg/kg	0.0050 U mg/kg	0.0050 U mg/kg	1.0 U µg/L	1.0 U µg/L	1.0 U µg/L	0.0050 U mg/kg	0.25 U mg/kg
Surrogate Bromofluorobenzene	30-137% (29-137%)	74%	102%	98%	78%	105%	103%	NA	NA	NA
Diesel Fuel #2	0.50 mg/kg (0.50 mg/L)	28 U mg/kg	29 U mg/kg	27 U mg/kg	27 U mg/kg	0.50 U mg/L	NA	NA	NA	NA
Jet Fuel	0.50 mg/kg (0.50 mg/L)	28 U mg/kg	29 U mg/kg	27 U mg/kg	27 U mg/kg	0.50 U mg/L	NA	NA	NA	NA
Unknown Hydrocarbon	0.50 mg/kg (0.50 mg/L)	28 U mg/kg	850 mg/kg y	800 mg/kg y	27 U mg/kg	0.50 U mg/L	NA	NA	NA	NA
Surrogate o-Terphenyl	75-125% (75-125%)	81%	104%	118%	113%	102%	NA	NA	NA	NA

[1] PS02531S04 is a field duplicate of PS0230S03.
[2] PS02229E05 is an equipment blank.
[3] PS02FQCT06 is a trip blank.
[4] Laboratory analytical results are presented in Appendix A.

U = Not Detected. Value listed is the detection limit.
NA = Not Analyzed or not applicable.
y = Chromatographic profile is not consistent with pattern(s) exhibited by reference fuel standards. Quantitation of unknown hydrocarbons in sample is based on diesel fuel

Source: ICF, 1995

APPENDIX B - 1e

ADDITIONAL SITE MAPS INCLUDING:

BEDROCK TOPOGRAPHY & STORM SEWER LINES

Source: HNUS, 1993

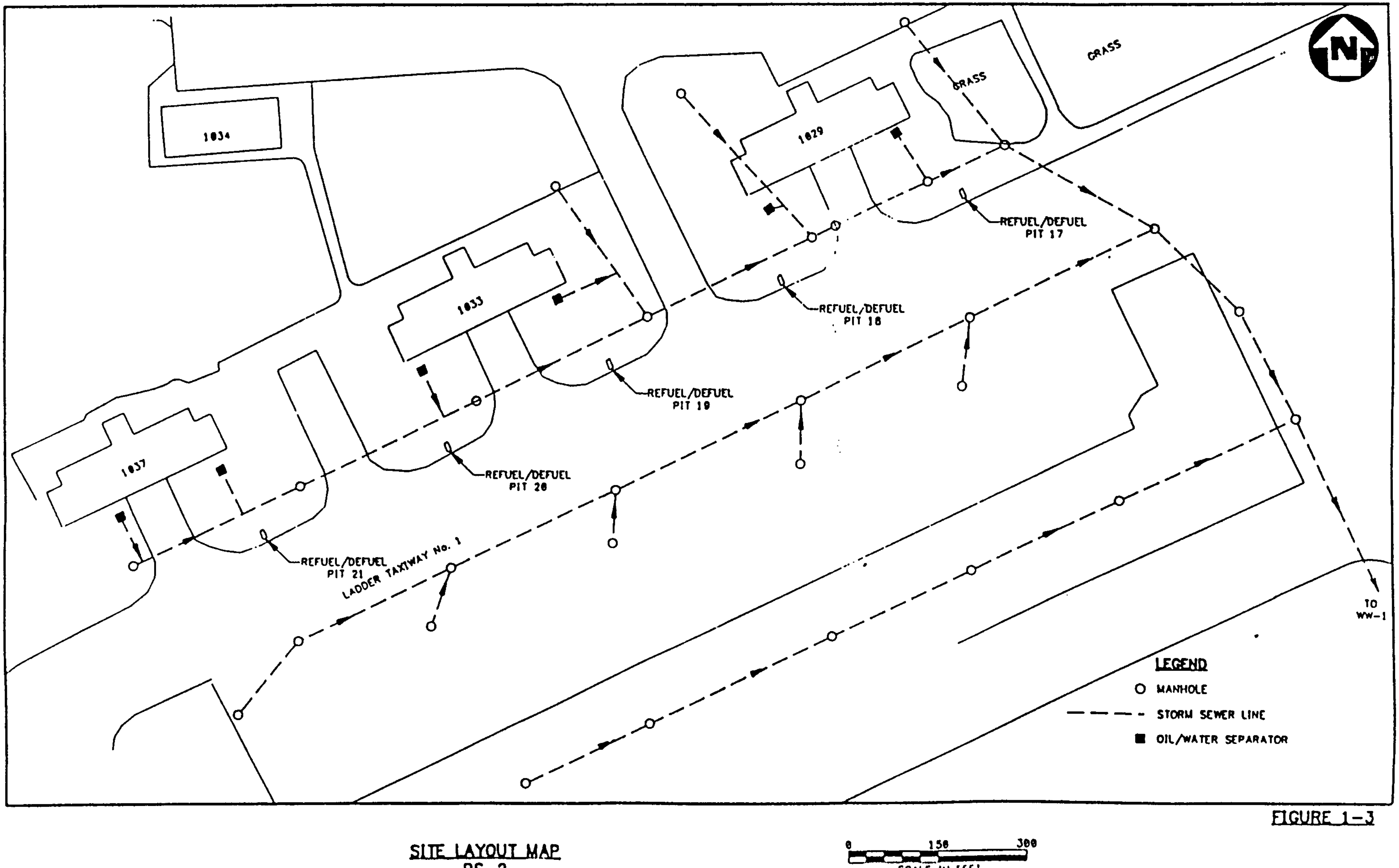
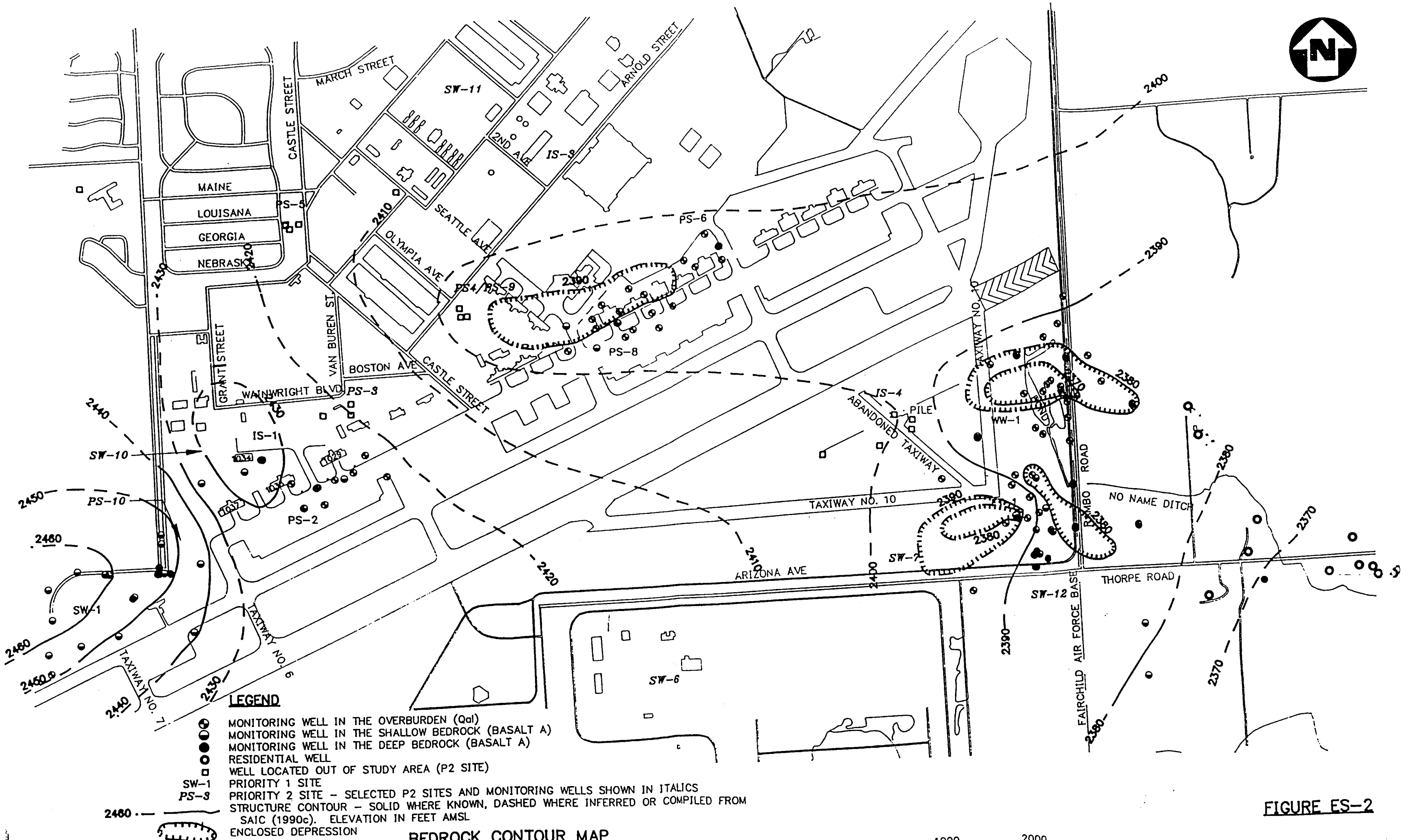


FIGURE 1-3

SITE LAYOUT MAP
PS-2
FAIRCHILD AIR FORCE BASE, WASHINGTON



BEDROCK CONTOUR MAP
TOP OF BASALT A
PRIORITY-1 SITES
FAIRCHILD AIR FORCE BASE, WASHINGTON

FIGURE ES-2

Source: HNUS, 1993